INDUSTRIAL SOLVENTS HANDBOOK

Fifth Edition

Edited by

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Contents and Subject Index

Introduction

A solution may be defined as a mixture of two or more substances which has uniform chemical and physical properties throughout. It may also be defined as a system whose component parts are two or more molecular species, there being no boundary surfaces between these parts larger than molecules. There are two components to every solution—the solvent and the solute. As a matter of convenience, the part of a solution which is in excess is designated as the solvent; the solute is the component which is in smaller proportion. Solvents, once used, may be recycled, reused, or discarded in an environmentally safe manner.

The purpose of solvents is to convert substances into a form suitable for a particular use. The importance of the role of solvents is brought out most clearly by the fact that many substances exhibit their greatest usefulness when in solution. Lacquer solvents, for example, are selected to produce homogeneous combinations and so selected as to impart the most desirable mechanical properties. The physical properties of a fabricated solution can be regulated at will by the proper choice of solvents, thus adapting them to the most varied uses and methods of applications. Some of the more important uses for solvents are in the adhesives, coatings, electronics, ink, pesticide, pharmaceutical, photographic reproduction, and textile industries. Large quantities of solvents are also involved in dry cleaning, metal degreasing, oil refining and recovery, and as fuel additives.

Solvents vary in their dissolving power, so that the line of demarcation between solvents, latent solvents and nonsolvents is difficult to define. Some of the factors which influence solvency are atmospheric conditions, purity and molecular association. Molecular aggregation is the explanation for increased, attenuated, or decreased solvent power or, more concisely, eccentric solvency. Any substance that will dissolve another is called a solvent. Thus, we have a gaseous solution when a liquid or a solid is dissolved in a gas; a liquid solution when any one of these is dissolved in a liquid, and a solid solution when any one of them is dissolved in a solid.

Mixing of solvents, diluents and thinners often results in change of solvent properties. Some chlorinated compounds become good solvents for cellulose esters when mixed with an alcohol. On the other hand, some active solvents for esters of cellulose lose some of their solvent power when mixed with hydrocarbons. Alcohols are added to lacquers to improve flow and to prevent blushing, although they vary considerably in these respects. Alcohols are not true or active solvents for nitrocellulose as are the active dissolvents like ethyl lactate or n-butyl acetate. The alcohol group, however, cannot be classed as nonsolvents like toluene or naphtha. When an alcohol is added to a true solvent, the solvent power of the latter is not reduced but, on the contrary, this active solvent activates the alcohol to such an extent that it too becomes a solvent. Therefore, alcohols are referred to as latent solvents, whose hidden solvent qualities are brought out by the addition of an active solvent. The presence of a latent solvent increases the tolerance of an active solvent for a nonsolvent. This group of latent solvents is also called extenders, because they increase the volume of a mixture without decreasing the solvent power.

In general, simple esters and ketones activate alcohols so that they too become solvents and are capable of tolerating various proportions of diluents. This is due to the molecular aggregates formed. Two-type solvents containing both an alcohol and an active solvent group, such as an ester, ether or ketone, activate alcohol to a lesser degree. Unit volumes of a solvent will activate only a limited amount of alcohol, indicating that definite molecular aggregates are formed. A mixture of 50% n-butyl acetate and 50% n-butyl alcohol will not lose its solvent power until 85 to 95% of the volume is evaporated, contributing further evidence of the validity of the theory of molecular aggregates. Plasticizers, which are the high-boiling solvents, also activate alcohols.

Liquids vary in their rate of evaporation. Naturally, in a mixture of liquids, some evaporate more rapidly than others. For example, if the solvent constituent of a lacquer evaporates more rapidly than the diluent, the limit of tolerance of the residual mixture is exceeded and gelling or precipitation occurs. As evaporation goes on, gigantic molecular reactions take place. Vast numbers of molecules change places as the new aggregates are formed. Some are

replaced and some are repelled, causing immiscibility, precipitation, blushing, or one or more of the many lacquer faults. It follows that dilution ratios do not indicate tolerance during the change of solvent-nonsolvent balance which occurs during drying.

In the theory of molecular aggregation, higher concentrations of cellulose derivatives contain fewer secondary-valence bonds. Consequently, smaller amounts of diluent can be tolerated. This condition occurs during film drying. Hydroxyl-containing solvents show greater tolerance for toluene than do the simpler esters. In the case of naphtha the condition is reversed. There are, however, exceptions to this statement, among which are butyl lactate and Butyl CELLOSOLVE, which have very high naphtha tolerance. Simple esters will tolerate 50 to 100% more naphtha than will such materials as ethyl lactate, ethyl ether, ethylene glycol, diacetone alcohol, and so forth. Ethers of glycols generally have higher dilution ratios than do the butyl esters with respect to benzene, toluene, and xylene.

Solutions of nitrocellulose tolerate larger quantities of nonsolvents than solutions of cellulose acetate. The "solvent-power number" is influenced by both the nature of the diluent and the mixing of two or more solvents. Frequently, when two or more nonsolvents are mixed, they may exhibit the qualities of a good solvent. This is especially true when one of the ingredients is an alcohol. The ether-alcohol solvent mixture for collodion is a familiar example. Another example of acquired solubility is the mixing of butyl acetate with amyl or ethyl alcohol for the less highly polymerized forms of glyceryl phthalate resins. Some of the chlorinated hydrocarbons will dissolve nitrocellulose when mixed with an alcohol. A mixture of benzene and alcohol will dissolve nitrocellulose containing up to 11% nitrogen. A toluene-ethyl alcohol solution of alkyd resin will dissolve nitrocellulose. In many cases the solvent property of esters for resins and nitrocellulose is increased by the addition of an alcohol. On the other hand, when active solvents for cellulose esters are mixed with aliphatic or aromatic hydrocarbons, the solvent power of these active solvents is decreased.

These facts bring to light reasons why many of the old-type solvents have been valued for their impurities. For example, methyl acetone, made from the distillation of wood, had particularly valuable solvent properties. Actually, it is a mixed solvent which consists of methanol, acetone, esters and higher ketones. This mixture has certain desirable properties not obtained by any of its component ingredients when used separately. For this reason the "synthetic methyl acetone" is made to simulate it. For this same reason commercial grades of butyl and amyl acetate contain 85% ester and the remaining portion is the corresponding alcohol. Amyl acetate, containing its characteristic impurities when manufactured from fusel oil, is also valued for its solvent properties. The synthetic product is different because it lacks these impurities. It is made from the pentane fraction of gasoline by chlorination; the chloropentane is hydrolyzed to form amyl alcohol, and is finally esterified to the acetate.

Because of today's concern with environmental pollution, chemical composition limitations of solvent formulations have been adopted by many state and local governmental agencies in the more highly industrialized areas of the country. These rules and regulations seriously affect the use of many solvents, and solvent blends must be reformulated to conform to the maximum allowable concentrations of the restricted solvents. It is necessary for the solvent user to acquaint himself with the governmental regulations of solvent use in his particular locale.

Hydrocarbon Solvents

PARAFFINS

Table 2.1: Methane *(4)*

FORMULA	CH_4	
PROPERTIES	RESEARCH GRADE	PURE GRADE
Composition, mol per cent		
Nitrogen	0.01	0.61
Carbon Dioxide		0.24
Methane	99.98	99.08
Ethylene		
Ethane	0.01	0.06
Propylene		
Propane		0.01
Freezing point, triple point, F	−296.46*	
Boiling point, F	−258.68*	
Specific gravity of liquid at 60/60 F		
at 20/4 C		
Density of liquid at 60 F, lb/gal		
Vapor pressure at 70 F, psia		
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	0.55491*	
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	23.6113*	
Density of real gas at 60 F and 14.7 psia, lbs/cu ft	0.04235	
Liquid volume, cu ft/lb at −260 F and 13.8 psia	0.03766*	
Critical temperature, F	−115.78*	
Critical pressure, psia	673.1*	
Flash point, approximate, F	−306*	
Flammability limits, volume % in air		
Lower	5.0*	
Higher	15.0*	
Heating value for real gas at 60 F and 30 in Hg, saturated basis BTU/ cu ft		994
Heating value for ideal gas at 60 F and 14.7 psia, BTU/cu ft,		
Dry basis	1010*	
Saturated basis		985

*Literature values.

Table 2.2: Ethane *(4)*

FORMULA	$CH_3–CH_3$	
PROPERTIES	RESEARCH GRADE	PURE GRADE
Composition, mol per cent		
Nitrogen		
Carbon Dioxide		
Methane		trace
Ethylene	trace	0.05
Ethane	99.97	99.35
Propylene	0.01	0.25
Propane	0.02	0.35
Freezing point, triple point, F	−297.89*	
Boiling point, F	−127.53*	
Specific gravity of liquid at 60/60 F	0.3771*	
at 20/4 C	0.362*	
Density of liquid at 60 F, lb/gal	3.144*	
Vapor pressure at 70 F, psia	560*	
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	1.0469*	
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	12.515*	
Density of real gas at 60 F and 14.7 psia, lbs/cu ft		
Liquid volume, cu ft/lb at −260 F and 13.8 psia	0.04252 (60 F)	
Critical temperature, F	90.32*	
Critical pressure, psia	707.8*	
Flash point, approximate, F	−211*	
Flammability limits, volume % in air		
Lower	2.9*	
Higher	13.0*	
Heating value for real gas at 60 F and 30 in Hg, saturated basis BTU/ cu ft		
Heating value for ideal gas at 60 F and 14.7 psia, BTU/cu ft,		
Dry basis	1769*	
Saturated basis		

*Literature values.

Table 2.3: Propane *(4)*

FORMULA	$CH_3-CH_2-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Ethane		0.07	0.01
Propylene		0.01	0.01
Propane	99.98	99.35	97.50
Isobutane	0.02	0.52	2.38
Normal Butane		0.05	0.10
Butene-2			
Neopentane			
Isopentane			
Normal Pentane			
Purity by freezing point, mol percent			
Freezing point, F	-305.84* (triple point)		
Boiling point, F	-43.73*		
Specific gravity of liquid at 60/60 F	0.5077*	0.508	0.510
20/4 C	0.5005*	0.501	
API gravity at 60 F		147.0	145.9
Density of liquid at 60 F, lb/gal		4.22	4.24
Vapor pressure at 70 F, psia		123	123
100 F, psia		189	189
130 F, psia		271	271
Sulfur content, weight per cent		< 0.0005	< 0.0005
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	1.5503*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	8.4515*		
Flash point, approximate, F	-156*		
Flammability limits, volume % in air			
Lower	2.1*		
Higher	9.5*		
Heating value for ideal gas at 60 F and 14.7 psia, dry basis BTU/cu ft	2517*		

*Literature

Table 2.4: Isobutane *(4)*

FORMULA	$CH_3-CH(CH_3)-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Ethane			
Propylene			
Propane		0.1	0.4
Isobutane	99.98	99.5	96.8
Normal Butane	0.02	0.4	2.8
Butene-2			
Neopentane			
Isopentane			
Normal Pentane			
Purity by freezing point, mol percent	99.96	99.5	
Freezing point, F	-255.28*		
Boiling point, F	10.89*		
Specific gravity of liquid at 60/60 F	0.5631*	0.563	0.563
20/4 C	0.5572*	0.557	0.557
API gravity at 60 F		119.8	119.8
Density of liquid at 60 F, lb/gal		4.68	4.68
Vapor pressure at 70 F, psia		45.8	45.4
100 F, psia		72.2	72.2
130 F, psia		111.5	111.5
Sulfur content, weight per cent		< 0.0005	< 0.0005
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	2.06805*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	6.3355*		
Flash point, approximate, F		-117	-117
Flammability limits, volume % in air			
Lower	1.8*		
Higher	8.4*		
Heating value for ideal gas at 60 F and 14.7 psia, dry basis BTU/cu ft	3253*		

*Literature values.

Table 2.5: n-Butane *(4)*

FORMULA	$CH_3–CH_2–CH_2–CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Ethane			
Propylene			
Propane			0.6
Isobutane	0.05	0.3	1.0
Normal Butane	99.95	99.4	97.6 95.0 min
Butene-2			0.1
Neopentane			0.2
Isopentane		0.2	0.3
Normal Pentane		0.1	0.2
Purity by freezing point, mol percent	99.95	99.4 99.0 min	
Freezing point, F	−217.03*		
Boiling point, F	31.10*		
Specific gravity of liquid at 60/60 F	0.5844*	0.584	0.584
20/4 C	0.5788*	0.579	0.579
API gravity at 60 F		110.8	110.8
Density of liquid at 60 F, lb/gal		4.86	4.86
Vapor pressure at 70 F, psia		31.6	32.0
100 F, psia		51.6	52.0
130 F, psia		82.2	83.0
Sulfur content, weight per cent		< 0.0005	< 0.0005
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	2.0757*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	6.3120*		
Flash point, approximate, F		−100	−100
Flammability limits, volume % in air			
Lower	1.8*		
Higher	8.4*		
Heating value for ideal gas at 60 F and 14.7 psia, dry basis BTU/cu ft	3262*		

*Literature values.

Table 2.6: 2,2-Dimethylpropane *(4)*

Neopentane

FORMULA	CH_3 $CH_3–C–CH_3$ CH_3		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Normal Butane	trace	0.1	1.7
cis-Butene-2		trace	0.1
2,2,-Dimethylpropane	99.99+	99.6	97.8
Isopentane			
Normal Pentane			0.4
Pentene-2			
Cyclopentane			
Purity by freezing point, mol per cent	99.99	99.3	
Freezing point, F	2.21*		
Boiling point, F	49.10*		
Distillation range, F			
Initial boiling point			
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			
Specific gravity of liquid at 60/60 F	0.5967*	0.597	0.597
at 20/4 C	0.5910*	0.591	0.591

(continued)

Table 2.6: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
API gravity at 60 F		105.5	105.5
Density of liquid at 60 F, lb/gal		4.96	4.96
Vapor pressure at 70 F, psia	21.9*	21.9	22.0
100 F, psia		35.9	36.7
130 F, psia		57.4	57.7
Refractive index, 20/D			
Color, Saybolt (unless indicated)	+30	+30	+30
Acidity, distillation residue		neutral	netural
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Kinematic viscosity, cs at 32 F	0.532*		
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	2.622*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	4.997*		
Flash point, approximate, F		−85	−85
Flammability limits, volume % in air			
Lower	1.4*		
Higher	8.3*		

*Literature values.

Table 2.7: Isopentane *(4)*

FORMULA	$CH_3-CH(CH_3)-CH_2-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Normal Butane		0.1	0.2
cis-Butene-2			
2,2,-Dimethylpropane		0.1	0.1
Isopentane	99.99	99.4	97.1
Normal Pentane	0.01	0.4	2.6
Pentene-2			
Cyclopentane			
Purity by freezing point, mol per cent	99.99	99.4	
Freezing point, F	−255.82*		
Boiling point, F	82.13*		
Distillation range, F			
Initial boiling point			82
10% Condensed			83
50% Condensed			83
90% Condensed			84
Dry point			86
Specific gravity of liquid at 60/60 F	0.6248*	0.625	0.625
at 20/4 C	0.61967*	0.620	0.620
API gravity at 60 F		94.9	94.9
Density of liquid at 60 F, lb/gal		5.20	5.20
Vapor pressure at 70 F, psia	11.57*	11.5	11.4
100 F, psia	20.44*	20.4	20.2
130 F, psia			33.5
Refractive index, 20/D	1.35373*		
Color, Saybolt (unless indicated)	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Kinematic viscosity, cs at 32 F	0.433*		
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	2.6269*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	4.9876*		
Flash point, approximate, F		−70	−70
Flammability limits, volume % in air			
Lower	1.4*		
Higher	8.3*		

*Literature values.

Table 2.8: n-Pentane *(4)*

FORMULA	$CH_3-CH_2-CH_2-CH_2-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Normal Butane			
cis-Butene-2			
2,2,-Dimethylpropane			
Isopentane	0.01	0.2	0.5
Normal Pentane	99.99	99.4	98.8
Pentene-2		0.1	0.2
Cyclopentane		0.3	0.5
Purity by freezing point, mol per cent	99.98	99.2	
Freezing point, F	−201.50*		
Boiling point, F	96.93*		
Distillation range, F			
Initial boiling point			96
10% Condensed			97
50% Condensed			97
90% Condensed			97
Dry point			99
Specific gravity of liquid at 60/60 F	0.6312*	0.631	0.633
at 20/4 C	0.62624*	0.626	
API gravity at 60 F		92.7	92.0
Density of liquid at 60 F, lb/gal		5.25	5.27
Vapor pressure at 70 F, psia	8.56*	8.6	
100 F, psia	15.57*	15.6	
130 F, psia	26.4*	26.3	
Refractive index, 20/D	1.35748*		
Color, Saybolt (unless indicated)	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Kinematic viscosity, cs at 32 F	0.431*		
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	2.6400*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	4.9629*		
Flash point, approximate, F		−57	−50
Flammability limits, volume % in air			
Lower	1.4*		
Higher	8.3*		

*Literature values.

Table 2.9: 2,2-Dimethylbutane *(4)*

Neohexane

FORMULA	$CH_3-C(CH_3)_2-CH_2-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Isopentane			
Cyclopentane		0.2	0.1
2,2-Dimethylbutane	99.98	99.5	96.4 95.0 min.
2,3-Dimethylbutane	0.01	0.2	2.2
2-Methylpentane	0.01	0.1	0.3
3-Methylpentane			
Purity by freezing point, mol per cent	99.97	99.4 99.0 min.	
Freezing point, F	−147.77*		
Boiling point, F	121.53*		
Distillation range, F			
Initial boiling point			120.5
Dry point			122.2

(continued)

Table 2.9: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Specific gravity of liquid at 60/60 F	0.6540*	0.655	0.659
at 20/4 C	0.64916*	0.650	0.654
API gravity at 60 F		84.5	83.2
Density of liquid at 60 F, lbs/gal		5.45	5.49
Vapor pressure at 70 F, psia	5.30*	5.3	5.3
100 F, psia	9.86*	9.9	9.9
130 F, psia	17.04*	16.8	16.8
Refractive index, 20/D	1.36876*	1.369	1.369
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		−25	−25
Flammability limits, volume % in air			
Lower	1.2*		
Higher	7.7*		

*Literature values.

Table 2.10: 2,3-Dimethylbutane *(4)*

Diisopropyl

FORMULA	$CH_3-CH(CH_3)-CH(CH_3)-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Isopentane			0.6
Cyclopentane			
2,2-Dimethylbutane	0.07	0.2	1.1
2,3-Dimethylbutane	99.88	99.7	98.0 95.0 min.
2-Methylpentane	0.04	0.1	0.2
3-Methylpentane	0.01		0.1
Purity by freezing point, mol per cent	99.88	99.3 99.0 min.	
Freezing point, F	−199.37*		
Boiling point, F	136.37*		
Distillation range, F			
Initial boiling point			135
Dry point			136
Specific gravity of liquid at 60/60 F	0.6664*	0.666	0.666
at 20/4 C	0.66164*	0.662	0.661
API gravity at 60 F		81.0	81.0
Density of liquid at 60 F, lbs/gal		5.54	5.54
Vapor pressure at 70 F, psia	3.87*	3.8	3.8
100 F, psia	7.40*	7.3	7.3
130 F, psia	13.12*	12.9	12.9
Refractive index, 20/D	1.37495*	1.375	1.375
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.006
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		−20	−20
Flammability limits, volume % in air			
Lower	1.2*		
Higher	7.7*		

*Literature values.

Table 2.11: 2-Methylpentane *(4)*

FORMULA	$CH_3-CH(CH_3)-CH_2-CH_2-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Isopentane			
Cyclopentane			0.2
2,2-Dimethylbutane			
2,3-Dimethylbutane	0.01	0.5	3.8
2-Methylpentane	99.98	99.3	95.4 95.0 min.
3-Methylpentane	0.01	0.2	0.6
Purity by freezing point, mol per cent	99.98	99.2 99.0 min.	
Freezing point, F	−244.61*		
Boiling point, F	140.49*		
Distillation range, F			
Initial boiling point			140
Dry point			141
Specific gravity of liquid at 60/60 F	0.6579*	0.658	0.658
at 20/4 C	0.65315*	0.653	0.653
API gravity at 60 F		85.2	85.2
Density of liquid at 60 F, lbs/gal		5.44	5.44
Vapor pressure at 70 F, psia	3.48*	3.5	3.5
100 F, psia	6.77*	6.8	6.8
130 F, psia	13.32*	13.0	13.0
Refractive index, 20/D	1.37145*	1.371	1.371
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		−10	−10
Flammability limits, volume % in air			
Lower	1.2*		
Higher	7.7*		

*Literature values.

Table 2.12: 3-Methylpentane *(4)*

FORMULA	$CH_3-CH_2-CH(CH_3)-CH_2-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
2,3-Dimethylbutane			0.1
2-Methylpentane	0.01	0.6	3.8
3-Methylpentane	99.99	99.4 99.0 min	0.02
Normal Hexane			
Methylcyclopentane			
2,2-Dimethylpentane			
2,4-Dimethylpentane			
Cyclohexane			
2,3-Dimethylpentane			
2-Methylhexane			
3-Methylhexane			
Purity by freezing point, mol per cent	**		
Freezing point, F	**		
Boiling point, F	145.91*		
Distillation range, F			
Initial boiling point			145
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			146

(continued)

Table 2.12: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Specific gravity of liquid at 60/60F	0.6690*	0.669	0.669
at 20/4 C	0.66431*	0.664	0.664
API gravity at 60 F		80.0	80.0
Density of liquid at 60 F, lbs/gal		5.57	5.57
Vapor pressure at 70 F, psia	3.11*	3.1	3.1
100 F, psia	6.10*	6.1	6.0
130 F, psia	11.03*	11.0	10.9
Refractive index, 20/D	1.37652*	1.376	1.376
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		−25	25
Flammability limits, volume % in air			
Lower	1.2*		
Higher	7.7*		

*Literature values. **Forms a glass.

Table 2.13: n-Hexane *(4)*

FORMULA	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
2,3-Dimethylbutane			
2-Methylpentane	trace	trace	trace
3-Methylpentane	0.02	0.1	0.2
Normal Hexane	99.98	99.5	97.7 95.0 min
Methylcyclopentane	trace	0.4	2.1
2,2-Dimethylpentane			
2,4-Dimethylpentane			
Cyclohexane			
2,3-Dimethylpentane			
2-Methylhexane			
3-Methylhexane			
Purity by freezing point, mol per cent	99.98	99.4	
Freezing point, F	−139.63*		
Boiling point, F	155.73*		
Distillation range, F			
Initial boiling point			155.1
10% Condensed			155.3
50% Condensed			155.3
90% Condensed			155.7
Dry point			156.4
Specific gravity of liquid at 60/60F	0.6640*	0.664	0.666
at 20/4 C	0.65937*	0.660	0.661
API gravity at 60 F		81.6	81.0
Density of liquid at 60 F, lbs/gal		5.53	5.54
Vapor pressure at 70 F, psia	2.46*	2.5	2.5
100 F, psia	4.96*	5.0	4.9
130 F, psia	9.17*	9.2	9.1
Refractive index, 20/D	1.37486*	1.375	1.375
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		−10	−10
Flammability limits, volume % in air			
Lower	1.2*		
Higher	7.7*		

*Literature values. **Forms a glass.

Table 2.14: 2,4-Dimethylpentane *(4)*

FORMULA	$CH_3-CH(CH_3)-CH_2-CH(CH_3)-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
2,3-Dimethylbutane			
2-Methylpentane			
3-Methylpentane			
Normal Hexane		trace	0.1
Methylcyclopentane			
2,2-Dimethylpentane	0.01	0.1	2.9
2,4-Dimethylpentane	99.99	99.7	96.0 95.0 min
Cyclohexane		0.1	0.5
2,3-Dimethylpentane		0.1	0.5
2-Methylhexane			
3-Methylhexane			
Purity by freezing point, mol per cent	99.77	99.2 99.0 min	
Freezing point, F	−182.64*		
Boiling point, F	176.90*		
Distillation range, F			
Initial boiling point			175
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			176
Specific gravity of liquid at 60/60F	0.6772*	0.677	0.678
at 20/4 C	0.67270*	0.673	0.673
API gravity at 60 F		77.4	77.2
Density of liquid at 60 F, lbs/gal		5.64	5.64
Vapor pressure at 70 F, psia	1.59*	1.6	1.6
100 F, psia	3.29*	3.3	3.3
130 F, psia	6.24*	6.2	6.2
Refractive index, 20/D	1.38145*	1.381	1.381
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight per cent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		10	10
Flammability limits, volume % in air			
Lower	1.0*		
Higher	7.0*		

*Literature values.

Table 2.15: 2,3-Dimethylpentane *(4)*

FORMULA	$CH_3-CH(CH_3)-CH(CH_3)-CH_2-CH_3$
PROPERTIES	**90% GRADE**
Composition, weight per cent	
2,3-Dimethylbutane	
2-Methylpentane	
3-Methylpentane	
Normal Hexane	
Methylcyclopentane	
2,2-Dimethylpentane	
2,4-Dimethylpentane	
Cyclohexane	
2,3-Dimethylpentane	90.4 90.0 min
2-Methylhexane	3.4
3-Methylhexane	6.2
Purity by freezing point, mol per cent	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	193
10% Condensed	
50% Condensed	
90% Condensed	
Dry point	194
Specific gravity of liquid at 60/60F	0.6990
at 20/4 C	0.6943
API gravity at 60 F	70.9
Density of liquid at 60 F, lbs/gal	5.82
Vapor pressure at 70 F, psia	1.2
100 F, psia	3.6
130 F, psia	
Refractive index, 20/D	1.3922
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight per cent	
Copper corrosion	
Doctor test	negative
Flash point, approximate, F	< 10
Flammability limits, volume % in air	
Lower	
Higher	

Table 2.16: 3-Methylhexane *(4)*

FORMULA	$CH_3-CH_2-CH(CH_3)-(CH_2)_2-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
2,3-Dimethylpentane	0.1
2-Methylhexane	1.4
3-Methylhexane	97.2 95.0 min
3-Ethylpentane	0.8
Normal Heptane	
Dimethylcyclopentane	0.5
Methylcyclohexane	
2,2-Dimethylhexane	
2,4-Dimethylhexane	
2,5-Dimethylhexane	
Other Dimethylhexanes	
2,2,4-Trimethylpentane	
2,2,3-Trimethylpentane	
2,3,4-Trimethylpentane	
2,3,3-Trimethylpentane	
Boiling point, F	
Distillation range, F	
Initial boiling point	195
Dry point	196
Specific gravity of liquid at 60/60 F	0.692
20/4 C	0.688
API gravity at 60 F	73.0
Density of liquid at 60 F, lbs/gal	5.76
Vapor pressure at 70 F, psia	
100 F, psia	2.1
130 F, psia	
Refractive index, 20/D	1.388
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	0.005
Copper corrosion	1
Doctor test	negative
Flash point, approximate, F	25 Estimated
Flammabilty limits, volume % in air	
Lower	1
Higher	7

Table 2.17: n-Heptane *(4)*

FORMULA	$CH_3-(CH_2)_5-CH_3$	
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
2,3-Dimethylpentane		
2-Methylhexane		
3-Methylhexane		
3-Ethylpentane		trace
Normal Heptane	99.99	99.8
Dimethylcyclopentane	0.01	0.2
Methylcyclohexane		trace
2,2-Dimethylhexane		
2,4-Dimethylhexane		
2,5-Dimethylhexane		
Other Dimethylhexanes		
2,2,4-Trimethylpentane		
2,2,3-Trimethylpentane		
2,3,4-Trimethylpentane		
2,3,3-Trimethylpentane		
Purity by freezing point, mol %	99.92	99.7 99.0 min
Freezing point, F	−131.10*	
Boiling point, F	209.17*	
Distillation range, F		
Initial boiling point		
Dry point		
Specific gravity of liquid at 60/60 F	0.6882*	0.688
20/4 C	0.68376*	0.684
API gravity at 60 F		74.1
Density of liquid at 60 F, lbs/gal		5.73
Vapor pressure at 70 F, psia		
100 F, psia	1.62*	1.6
130 F, psia		
Refractive index, 20/D	1.38764*	1.388
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Sulfur content, weight percent		0.005
Copper corrosion		1
Doctor test		negative
Flash point, approximate, F		25
Flammabilty limits, volume % in air		
Lower		1.0*
Higher		7.0*

*Literature values.

Table 2.18: 2,2,4-Trimethylpentane *(4)*

Isooctane

FORMULA	$CH_3-C(CH_3)_2-CH_2-CH(CH_3)-CH_3$	
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
2,3-Dimethylpentane		
2-Methylhexane		
3-Methylhexane		
3-Ethylpentane		
Normal Heptane		trace
Dimethylcyclopentane		
Methylcyclohexane		
2,2-Dimethylhexane	0.01	0.2
2,4-Dimethylhexane		
2,5-Dimethylhexane		
Other Dimethylhexanes		
2,2,4-Trimethylpentane	99.99	99.8
2,2,3-Trimethylpentane		
2,3,4-Trimethylpentane		
2,3,3-Trimethylpentane		
Purity by freezing point, mol %	99.98	99.7 99.0 min
Freezing point, F	−161.28*	
Boiling point, F	210.63*	
Distillation range, F		
Initial boiling point		
Dry point		
Specific gravity of liquid at 60/60 F	0.6963*	0.696
20/4 C	0.69193*	0.692
API gravity at 60 F		71.7
Density of liquid at 60 F, lbs/gal		5.80
Vapor pressure at 70 F, psia	0.79*	0.8
100 F, psia	1.71*	1.7
130 F, psia	3.37*	3.3
Refractive index, 20/D	1.39145*	1.391
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Sulfur content, weight percent		0.005
Copper corrosion		1
Doctor test		negative
Flash point, approximate, F		18
Flammabilty limits, volume % in air		
Lower		
Higher		

*Literature values.

Table 2.19: 2,3,4-Trimethylpentane *(4)*

FORMULA	$CH_3-CH(CH_3)-CH(CH_3)-CH(CH_3)-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
2,3-Dimethylpentane			
2-Methylhexane			
3-Methylhexane			
3-Ethylpentane			
Normal Heptane			
Dimethylcyclopentane			
Methylcyclohexane			
2,2-Dimethylhexane			
2,4-Dimethylhexane			
2,5-Dimethylhexane			
Other Dimethylhexanes	trace	trace	0.6
2,2,4-Trimethylpentane			
2,2,3-Trimethylpentane			
2,3,4-Trimethylpentane	99.99+	99.8	98.0 95.0 min
2,3,3-Trimethylpentane	trace	0.2	1.4
Purity by freezing point, mol %		99.1 99.0 min	
Freezing point, F	−164.58*		
Boiling point, F	236.24*		
Distillation range, F			
Initial boiling point			
Dry point			
Specific gravity of liquid at 60/60 F	0.7233*	0.723	0.723
20/4 C	0.71906*	0.719	0.719
API gravity at 60 F		64.1	64.1
Density of liquid at 60 F, lbs/gal		6.02	6.02
Vapor pressure at 70 F, psia			
100 F, psia	0.98*	1.0	1.0
130 F, psia			
Refractive index, 20/D	1.40422*	1.404	1.404
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F	41 (D 56)	41 (D 56)	41 (D 56)
Flammabilty limits, volume % in air			
Lower			
Higher			

*Literature values.

Table 2.20: Mixed Trimethylpentanes *(4)*

FORMULA	C_8H_{18}
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
2,3-Dimethylpentane	
2-Methylhexane	
3-Methylhexane	
3-Ethylpentane	
Normal Heptane	
Dimethylcyclopentane	
Methylcyclohexane	
2,2-Dimethylhexane	0.3
2,4-Dimethylhexane	0.1
2,5-Dimethylhexane	0.1
Other Dimethylhexanes	3.5
2,2,4-Trimethylpentane	
2,2,3-Trimethylpentane	0.1 }
2,3,4-Trimethylpentane	80.9 } 95.0 min
2,3,3-Trimethylpentane	15.0 }
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	235
Dry point	236
Specific gravity of liquid at 60/60 F	0.723
20/4 C	0.719
API gravity at 60 F	64.2
Density of liquid at 60 F, lbs/gal	6.02
Vapor pressure at 70 F, psia	
100 F, psia	1.0
130 F, psia	
Refractive index, 20/D	1.404
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	0.005
Copper corrosion	1
Doctor test	negative
Flash point, approximate, F	50
Flammabilty limits, volume % in air	
Lower	
Higher	

Table 2.21: Mixed Dimethylhexanes *(4)*

FORMULA	C_8H_{18}
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
2,3-Dimethylpentane	
2-Methylhexane	
3-Methylhexane	
3-Ethylpentane	
Normal Heptane	
Dimethylcyclopentane	
Methylcyclohexane	
2,2-Dimethylhexane	4.3 }
2,4-Dimethylhexane	36.7 } 95.0 min
2,5-Dimethylhexane	53.9 }
Other Dimethylhexanes	
2,2,4-Trimethylpentane	1.6
2,2,3-Trimethylpentane	3.5
2,3,4-Trimethylpentane	
2,3,3-Trimethylpentane	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
PROPERTIES	**TECHNICAL GRADE**
Distillation range, F	
Initial boiling point	228.6
Dry point	228.8
Specific gravity of liquid at 60/60 F	0.704
20/4 C	0.700
API gravity at 60 F	69.4
Density of liquid at 60 F, lbs/gal	5.86
Vapor pressure at 70 F, psia	
100 F, psia	1.0
130 F, psia	
Refractive index, 20/D	1.394
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	0.005
Copper corrosion	1
Doctor test	negative
Flash point, approximate, F	50
Flammabilty limits, volume % in air	
Lower	
Higher	

*Literature values.

Table 2.22: n-Oxtane *(4)*

FORMULA	$CH_3-(CH_2)_6-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Isooctanes	0.02	0.3	0.7
Normal Octane	99.92	99.6	98.7
2,2,5-Trimethylhexane			
2,2,4-Trimethylhexane			
Isononanes	0.06	0.1	0.6
Isoparaffins			
Normal Nonane			
Purity by freezing point, mol %	99.88	99.2 99.0 min	96.2 99.0 min
Freezing point, F	−70.23*		
Boiling point, F	258.20*		
Distillation range, F			
Initial boiling point			
Dry point			
Specific gravity of liquid at 60/60 F	0.7068*	0.707	0.707
at 20/4 C	0.70252*	0.702	0.702
API gravity at 60 F		68.6	68.2
Density of liquid at 60 F, lbs/gal		5.89	5.89
Vapor pressure at 70 F, psia			
100 F, psia	0.54*	0.5	0.5
130 F, psia			
Refractive index, 20/D	1.39743*	1.397	1.397
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		72	72

*Literature values.

Table 2.23: 2,2,5-Trimethylhexane *(4)*

FORMULA	$CH_3-C(CH_3)_2-CH_2-CH_2-CH(CH_3)-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Isooctanes			
Normal Octane			
2,2,5-Trimethylhexane	99.99	99.6	97.2 95.0 min
2,2,4-Trimethylhexane	0.01	0.4	2.8
Isononanes			
Isoparaffins			
Normal Nonane			
Purity by freezing point, mol %	99.80	99.3 99.0 min	
Freezing point, F	−158.40*		
Boiling point, F	255.35		
Distillation range, F			
Initial boiling point			
Dry point			
Specific gravity of liquid at 60/60 F	0.7174*	0.717	0.717
at 20/4 C	0.70721*	0.707	0.707
API gravity at 60 F		65.7	65.7
Density of liquid at 60 F, lbs/gal		5.97	5.97
Vapor pressure at 70 F, psia	0.26*	0.3	0.3
100 F, psia	0.62*	0.6	0.6
130 F, psia	1.34*	1.3	1.3
Refractive index, 20/D	1.39972*	1.400	1.400
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	netural
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		55	55

*Literature values.

Table 2.24: n-Nonane *(4)*

FORMULA	$CH_3-(CH_2)_7-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Isooctanes			
Normal Octane			
2,2,5-Trimethylhexane			
2,2,4-Trimethylhexane			
Isononanes			
Isoparaffins	0.1	0.4	0.5
Normal Nonane	99.9	99.6	99.5
Purity by freezing point, mol %	99.67	99.2 99.0 min	95.9 95.0 min
Freezing point, F	−64.33*		
Boiling point, F	303.44		
Distillation range, F			
Initial boiling point			303.4
Dry point			304.0
Specific gravity of liquid at 60/60 F	0.7217*	0.722	0.722
at 20/4 C	0.71763*	0.718	0.718
API gravity at 60 F		64.4	64.4
Density of liquid at 60 F, lbs/gal		6.01	6.01
Vapor pressure at 70 F, psia			
100 F, psia	0.18*	0.2	0.2
130 F, psia			
Refractive index, 20/D	1.40542*	1.405	1.397
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent			
Copper corrosion			
Doctor test			
Flash point, approximate, F		86	86

*Literature values.

Table 2.25: n-Decane *(4)*

FORMULA	$CH_3-(CH_2)_8-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight per cent			
Normal Nonane	0.05		
Normal Decane	99.94	99.5	99.0
Normal Undecane			
Normal Dodecane			
Normal Tridecane			
Isoparaffins	0.01	0.5	1
Purity by freezing point, mol %	99.55	99.1 99.0 min	96.5 95.0 min
Freezing point, F	−21.39*		
Boiling point, F	345.42*		
Distillation range, F			
Initial boiling point			344.9
Dry Point			345.4
Specific gravity of liquid at 60/60 F	0.7341*	0.734	0.734
at 20/4 C	0.73005*	0.730	0.730
API gravity at 60 F		61.3	61.3
Density of liquid at 60 F, lbs/gal		6.11	6.11
Vapor pressure at 100 F, psia		0.1	0.1
Refractive index, 20/D	1.41189*	1.412	1.412
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		111	111

*Literature values.

Table 2.26: n-Undecane *(4)*

FORMULA	$CH_3-(CH_2)_9-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Normal Nonane			
Normal Decane			
Normal Undecane	99.8	99.6	99.1
Normal Dodecane			
Normal Tridecane			
Isoparaffins	0.2	0.4	0.9
Purity by freezing point, mol %	99.64	99.1 99.0 min	96.7 95.0 min
Freezing point, F	−14.07*		
Boiling point, F	384.60*		
Distillation range, F			
Initial boiling point			384
Dry Point			385
Specific gravity of liquid at 60/60 F	0.7443*	0.744	0.744
at 20/4 C	0.74024*	0.740	0.739
API gravity at 60 F		58.7	58.7
Density of liquid at 60 F, lbs/gal		6.19	6.19
Vapor pressure at 100 F, psia			
Refractive index, 20/D	1.41725*	1.417	1.419
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		149	149

*Literature values.

Table 2.27: n-Dodecane *(4)*

FORMULA	$CH_3-(CH_2)_{10}-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight per cent			
Normal Nonane			
Normal Decane			
Normal Undecane	0.05	0.1	0.3
Normal Dodecane	99.95	99.9	99.7
Normal Tridecane			trace
Isoparaffins			
Purity by freezing point, mol %	99.70	99.3 99.0 min	95.5 95.0 min
Freezing point, F	14.74*		
Boiling point, F	421.30*		
Distillation range, F			
Initial boiling point		419	418
Dry Point		424	424
Specific gravity of liquid at 60/60 F	0.7526*	0.753	0.753
at 20/4 C	0.74869*	0.749	
API gravity at 60 F		56.4	56.4
Density of liquid at 60 F, lbs/gal		6.27	6.26
Vapor pressure at 100 F, psia			
Refractive index, 20/D	1.42160*	1.422	1.422
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		160	160

*Literature values.

Table 2.28: n-Tridecane *(4)*

FORMULA	$CH_3-(CH_2)_{11}-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight percent			
Normal Tridecane	99.9	99.8	99.2
Normal Tetradecane			
Normal Pentadecane			
Normal Hexadecane			
Normal Heptadecane			
Isoparaffins	0.1	0.2	0.8
Purity by freezing point, mol %	99.80	99.49 99.0 min	96.81 95.0 min
Freezing point, F	22.29*		
Boiling point, F	455.78*		
Distillation range, F			
Initial boiling point			452
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			458
Specific gravity of liquid at 60/60 F	0.7601*	0.760	0.762
at 20/4 C	0.75622*	0.756	0.758
API gravity at 80 F			
API gravity at 60 F		54.7	54.2
Density of liquid at 60 F, lbs/gal		6.33	6.34
Refractive index, 20/D	1.42560*	1.426	1.427
Color, Gardner			
Acidity, distillation residue		neutral	neutral
Sulfur content, weight percent		0.005	0.005
Bromine number			
Kinematic viscosity, cs at 77 F			2.25
Flash point, approximate, F		175 (D-56)	175 (D-56)

*Literature values

Table 2.29: n-Tetradecane *(4)*

FORMULA	$CH_3-(CH_2)_{12}-CH_3$	
PROPERTIES	PURE GRADE	TECHNICAL GRADE
Composition, weight percent		
Normal Tridecane		
Normal Tetradecane	99.6	99
Normal Pentadecane		
Normal Hexadecane		
Normal Heptadecane		
Isoparaffins	0.4	1
Purity by freezing point, mol %	99.14	95.8 95.0 min
Freezing point, F	42.55*	
Boiling point, F	488.33*	
Distillation range, F		
Initial boiling point		485
10% Condensed		
50% Condensed		
90% Condensed		
Dry point		492
Specific gravity of liquid at 60/60 F	0.7667*	0.769
at 20/4 C	0.76276*	0.765
API gravity at 80 F		
API gravity at 60 F		52.5
Density of liquid at 60 F, lbs/gal		6.40
Refractive index, 20/D	1.42892*	1.430
Color, Gardner	1	1
Acidity, distillation residue		
Sulfur content, weight percent		
Bromine number		
Kinematic viscosity, cs at 77 F		
Flash point, approximate, F	250**	250**

*Literature values

Table 2.30: n-Pentadecane *(4)*

FORMULA	$CH_3-(CH_2)_{13}-CH_3$
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
Normal Tridecane	
Normal Tetradecane	
Normal Pentadecane	99.7
Normal Hexadecane	
Normal Heptadecane	
Isoparaffins	0.3
Purity by freezing point, mol %	96.80 95.0 min
Freezing point, F	48.74
Boiling point, F	
Distillation range, F	
Initial boiling point	502
10% Condensed	512
50% Condensed	514
90% Condensed	516
Dry point	
Specific gravity of liquid at 60/60 F	0.7721*
at 20/4 C	0.76830*
API gravity at 80 F	
API gravity at 60 F	51.77*
Density of liquid at 60 F, lbs/gal	6.43*
Refractive index, 20/D	1.4332
Color, Gardner	< 1
Acidity, distillation residue	
Sulfur content, weight percent	
Bromine number	0.10
Kinematic viscosity, cs at 77 F	
Flash point, approximate, F	270

*Literature values

Table 2.31: n-Hexadecane *(4)*

FORMULA	$CH_3-(CH_2)_{14}-CH_3$
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
Normal Tridecane	
Normal Tetradecane	
Normal Pentadecane	0.2
Normal Hexadecane	99.6
Normal Heptadecane	
Isoparaffins	0.2
Purity by freezing point, mol %	96.35 95.0 min
Freezing point, F	63.79
Boiling point, F	
Distillation range, F	
Initial boiling point	521
10% Condensed	531
50% Condensed	531
90% Condensed	533
Dry point	540
Specific gravity of liquid at 60/60 F	
at 20/4 C	
API gravity at 80 F	51.8
API gravity at 60 F	49.9†
Density of liquid at 60 F, lbs/gal	6.49
Refractive index, 20/D	1.4352
Color, Gardner	< 1
Acidity, distillation residue	
Sulfur content, weight percent	
Bromine number	0.21
Kinematic viscosity, cs at 77 F	
Flash point, approximate, F	275

*Literature values

Table 2.32: n-Heptadecane *(4)*

FORMULA	$CH_3-(CH_2)_{16}-CH_3$
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
Normal Tridecane	
Normal Tetradecane	
Normal Pentadecane	
Normal Hexadecane	0.3
Normal Heptadecane	99.4
Isoparaffins	0.3
Purity by freezing point, mol %	96.60 95.0 min
Freezing point, F	70.47
Boiling point, F	
Distillation range, F	5 mm Hg
Initial boiling point	289
10% Condensed	291
50% Condensed	292
90% Condensed	292
Dry point	
Specific gravity of liquid at 60/60 F	
at 20/4 C	
API gravity at 80 F	50.8
API gravity at 60 F	48.9†
Density of liquid at 60 F, lbs/gal	6.53
Refractive index, 20/D	
Color, Gardner	< 1
Acidity, distillation residue	
Sulfur content, weight percent	
Bromine number	0.43
Kinematic viscosity, cs at 77 F	
Flash point, approximate, F	300

*Literature values

Table 2.33: n-Octadecane *(4)*

FORMULA	$CH_3-(CH_2)_{16}-CH_3$
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
Normal Hexadecane	0.1
Normal Heptadecane	0.3
Normal Octadecane	99.2
Normal Nonadecane	
Normal Eicosane	
Isoparaffins	0.4
Purity by freezing point, mol %	95.95 95.0 min
Freezing point, F	81.82
Distillation range, F	5 mm Hg
Initial boiling point	302
10% Condensed	310
50% Condensed	312
90% Condensed	312
95% Condensed	313
API gravity at 100 F	51.8
API gravity at 60 F	48.0†
Density of liquid at 60 F, lbs/gal	6.56
Color, Gradner	1
Bromine number	0.48
Flash point, approximate, F	330

†API gravity at 60 F is corrected from 100F.

Table 2.34: n-Nonadecane *(4)*

FORMULA	$CH_3-(CH_2)_{17}-CH_3$
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
Normal Hexadecane	
Normal Heptadecane	
Normal Octadecane	0.5
Normal Nonadecane	99.3
Normal Eicosane	
Isoparaffins	0.2
Purity by freezing point, mol %	95.37 95.0 min
Freezing point, F	87.98
Distillation range, F	5 mm Hg
Initial boiling point	320
10% Condensed	333
50% Condensed	336
90% Condensed	336
95% Condensed	336
API gravity at 100 F	51.0
API gravity at 60 F	47.3†
Density of liquid at 60 F, lbs/gal	6.59
Color, Gradner	1
Bromine number	0.53
Flash point, approximate, F	335

†API gravity at 60 F is corrected from 100F.

Table 2.35: n-Eicosane *(4)*

FORMULA	$CH_3-(CH_2)_{18}-CH_3$
PROPERTIES	**90% GRADE**
Composition, weight percent	
Normal Hexadecane	
Normal Heptadecane	
Normal Octadecane	
Normal Nonadecane	1.25
Normal Eicosane	98.75
Isoparaffins	
Purity by freezing point, mol %	91.83 90.0 min
Freezing point, F	95.83

PROPERTIES	90% GRADE
Distillation range, F	5 mm Hg
Initial boiling point	340
10% Condensed	352
50% Condensed	354
90% Condensed	355
95% Condensed	356
API gravity at 100 F	49.7
API gravity at 60 F	46.1†
Density of liquid at 60 F, lbs/gal	6.63
Color, Gradner	1
Bromine number	0.74
Flash point, approximate, F	360

†API gravity at 60 F is corrected from 100F.

CYCLOPARAFFINS

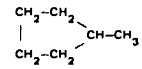
Table 2.36: Cyclopentane *(4)*

FORMULA: $\begin{matrix} CH_2-CH_2 \\ | \\ CH_2-CH_2 \end{matrix} > CH_2$

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE	90% GRADE
Composition, weight percent				
Normal Pentane		0.2	2.0	
Cyclopentane	99.97	99.5	97.4 95.0 min	93 90 min
2,2-Dimethylbutane	0.03	0.1	0.1	**
Normal Hexane			0.2	
Methylcyclopentane		0.2	0.3	
Purity by freezing point, mol %	99.97	99.5 99.0 min		
Freezing point, F	−136.96*			
Boiling point, F	120.67*			
Distillation range, F				
Initial boiling point			120.6	120.4
10% Condensed				120.9
50% Condensed				120.9
90% Condensed				121.1
Dry point			120.8	121.5
Specific gravity of liquid at 60/60 F	0.7505*	0.750	0.749	0.744
at 20/4 C	0.74538*	0.745	0.745	
API gravity at 60 F		57.2	57.2	58.8
Density of liquid at 60 F, lbs/gal		6.24	6.24	6.19
Vapor pressure at 70 F, psia	5.25*	5.3	5.3	
100 F, psia	9.91*	9.9	9.9	10.0
130 F, psia	17.37*	17.4	17.4	
Refractive index, 20/D	1.40645*	1.406	1.405	1.404
Color, Saybolt	+30	+30	+30	
Acidity, distillation residue		neutral	neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005	0.0005
Sulfur content, weight percent				0.006
Kauri Butanol value				53.4
Aniline point, F				70.5
Copper corrosion				1
Doctor test		negative	negative	negative
Flash point, approximate, F		−35	−35	−35

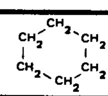
*Literature values.
**Major impurities are 2,2-Dimethylbutane and 2,3-Dimethylbutane.

Table 2.37: Methylcyclopentane *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Normal Hexane	0.06	0.4	2.0
Methylcyclopentane	99.94	99.5	96.5 95.0 min
2,4-Dimethylpentane		0.1	
Cyclohexane			1.5
Isoheptanes			
3,3-Dimethylpentane			
Benzene & Toluene, ppm			
1,1-Dimethylcyclopentane			
1,2 & 1,3-Dimethylcyclopentane			
Purity by freezing point, mol %	99.94	99.3 99.0 min	
Freezing point, F	−224.42*		
Boiling point, F	161.26*		
Distillation range, F			
Initial boiling point			161
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			162
Specific gravity of liquid at 60/60 F	0.7535*	0.754	0.754
at 20/4 C	0.74864*	0.749	0.749
API gravity at 60 F		56.2	56.2
Density of liquid at 60 F, lbs/gal		6.28	6.28
Vapor pressure at 70 F, psia	2.24*	2.2	2.3
100 F, psia	4.50*	4.5	4.5
130 F, psia	8.33*	8.3	8.3
Refractive index, 20/D	1.40970*	1.410	1.410
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent		0.005	0.005
Aniline point, F			
Kauri Butanol value			
Copper corrosion		1	1
Doctor test		negative	negative
Kinematic viscosity, cs at 32 F		–	
Flash point, approximate, F		−17	−17

*Literature values.

Table 2.38: Cyclohexane *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**99.5% GRADE**	**98.0% GRADE**
Composition, weight percent			
Normal Hexane			
Methylcyclopentane			0.5
2,4-Dimethylpentane	0.01	0.1	0.1
Cyclohexane	99.98	99.8 99.5 min	98.8 98.0 min
Isoheptanes		0.1	0.4
3,3-Dimethylpentane	0.01		0.2
Benzene & Toluene, ppm		193 500 max	200 500 max
1,1-Dimethylcyclopentane			
1,2 & 1,3-Dimethylcyclopentane			
Purity by freezing point, mol %	99.98		98.8
Freezing point, F	43.80*		

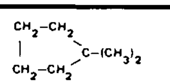
(continued)

Table 2.38: (continued)

PROPERTIES	RESEARCH GRADE	99.5% GRADE	98.0% GRADE
Boiling point, F	177.33*		
Distillation range, F			
Initial boiling point		177.3 175.1 min	177.3 175.1 min
10% Condensed			
50% Condensed			
90% Condensed			
Dry point		177.8 179.6 max	177.8 179.6 max
Specific gravity of liquid at 60/60 F	0.7834*	0.783	0.781
at 20/4 C	0.77855*	0.779	0.778
API gravity at 60 F	49.1*	49.3	49.6
Density of liquid at 60 F, lbs/gal	6.53*	6.52	6.51
Vapor pressure at 70 F, psia			
100 F, psia	3.26*	3.3 3.5 max	3.3 3.5 max
130 F, psia			
Refractive index, 20/D	1.42623*	1.426	1.424
Color, Saybolt	+30	+30 +30 min	+30 +30 min
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0007 0.0010 max	0.0007 0.0010 max
Sulfur content, weight percent		1 ppm 5 ppm max	1 ppm 5 ppm max
Aniline point, F			
Kauri Butanol value		56	55.1
Copper corrosion		1 1 max	1 1 max
Doctor test		neg. neg.	neg. neg.
Kinematic viscosity, cs at 32 F			0.94
Flash point, approximate, F		10	–1

*Literature values.

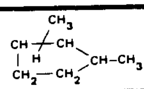
Table 2.39: 1,1-Dimethylcyclopentane *(4)*

FORMULA	
PROPERTIES	**90% GRADE**
Composition, weight percent	
Normal Hexane	
Methylcyclopentane	
2,4-Dimethylpentane	
Cyclohexane	
Isoheptanes	
3,3-Dimethylpentane	
Benzene & Toluene, ppm	
1,1-Dimethylcyclopentane	92*
1,2 & 1,3-Dimethylcyclopentane	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	189
10% Condensed	190
50% Condensed	190
90% Condensed	190
Dry point	190

PROPERTIES	90% GRADE
Specific gravity of liquid at 60/60 F	0.754
at 20/4 C	0.749
API gravity at 60 F	
Density of liquid at 60 F, lbs/gal	
Vapor pressure at 70 F, psia	
100 F, psia	
130 F, psia	
Refractive index, 20/D	
Color, Saybolt	
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	
Sulfur content, weight percent	
Aniline point, F	117
Kauri Butanol value	42.9
Copper corrosion	
Doctor test	
Kinematic viscosity, cs at 32 F	
Flash point, approximate, F	< 70

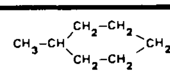
*Major impurities are: Cyclohexane, 3,3-Dimethylpentane and 2-Methylhexane.

Table 2.40: 1,2- and 1,3-Dimethylcyclopentane *(4)*

FORMULA	
PROPERTIES	**90% GRADE**
Composition, weight percent	
Normal Hexane	
Methylcyclopentane	
2,4-Dimethylpentane	
Cyclohexane	
Isoheptanes	
3,3-Dimethylpentane	
Benzene & Toluene, ppm	
1,1-Dimethylcyclopentane	
1,2 & 1,3-Dimethylcyclopentane	92†
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	196
10% Condensed	197
50% Condensed	197
90% Condensed	197
Dry point	197
Specific gravity of liquid at 60/60 F	0.748
at 20/4 C	0.744
API gravity at 60 F	
Density of liquid at 60 F, lbs/gal	
Vapor pressure at 70 F, psia	
100 F, psia	
130 F, psia	
Refractive index, 20/D	
Color, Saybolt	
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	
Sulfur content, weight percent	
Aniline point, F	120
Kauri Butanol value	40.5
Copper corrosion	
Doctor test	
Kinematic viscosity, cs at 32 F	
Flash point, approximate, F	< 70

†Major impurity is 3-Methylhexane.

Table 2.41: Methylcyclohexane *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
1,2-Dimethylcyclopentane	0.08	0.4	1.1
Normal Heptane		trace	0.4
Methylcyclohexane	99.90	99.4	97.9 95.0 min
Ethylcyclopentane		trace	0.1
Toluene	0.02	0.2	0.5
trans-1,4-Dimethylcyclohexane			
cis-1,4-Dimethylcyclohexane			
Other Dimethylcyclohexanes			
trans-1,2-Dimethylcyclohexane			
cis-1,2-Dimethylcyclohexane			
ortho-Xylene			
Unidentified Impurities			
Purity by freezing point, mol %	99.86	99.3 99.0 min	
Freezing point, F	−195.87*	−196.20	
Boiling point, F	213.68*		
Distillation range, F			
Initial boiling point			211
50% Condensed			
Dry point			213
Specific gravity of liquid at 60/60 F	0.7740*	0.774	0.774
at 20/4 C	0.76939*	0.769	0.769
API gravity at 60 F		51.3	51.3
Density of liquid at 60 F, lbs/gal		6.44	6.44
Vapor pressure at 70 F, psia			
100 F, psia	1.61*	1.6	1.6
Refractive index, 20/D	1.42312*	1.423	1.423
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		22	22

*Literature values.

Table 2.42: trans-1,4-Dimethylcyclohexane *(4)*

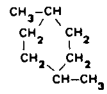
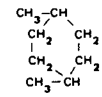
FORMULA	
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
1,2-Dimethylcyclopentane	
Normal Heptane	
Methylcyclohexane	
Ethylcyclopentane	
Toluene	
trans-1,4-Dimethylcyclohexane	99.6
cis-1,4-Dimethylcyclohexane	
Other Dimethylcyclohexanes	
trans-1,2-Dimethylcyclohexane	
cis-1,2-Dimethylcyclohexane	
ortho-Xylene	
Unidentified Impurities	0.4
Purity by freezing point, mol %	95.03 95.0 min
Freezing point, F	−37.97
Boiling point, F	
Distillation range, F	
Initial boiling point	245
50% Condensed	
Dry point	248
Specific gravity of liquid at 60/60 F	0.7704
at 20/4 C	0.7661
API gravity at 60 F	52.2
Density of liquid at 60 F, lbs/gal	6.41
Vapor pressure at 70 F, psia	0.4
100 F, psia	2.0
Refractive index, 20/D	1.4229
Color, Saybolt	+28
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	
Copper corrosion	
Doctor test	negative
Flash point, approximate, F	40 (D 56)

Table 2.43: cis-1,4-Dimethylcyclohexane *(4)*

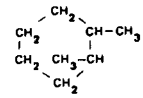
FORMULA	
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
1,2-Dimethylcyclopentane	
Normal Heptane	
Methylcyclohexane	
Ethylcyclopentane	
Toluene	
trans-1,4-Dimethylcyclohexane	0.11
cis-1,4-Dimethylcyclohexane	99.89
Other Dimethylcyclohexanes	
trans-1,2-Dimethylcyclohexane	
cis-1,2-Dimethylcyclohexane	
ortho-Xylene	
Unidentified Impurities	
Purity by freezing point, mol %	97.4 95.0 min
Freezing point, F	−125.38*
Boiling point, F	255.78*
Distillation range, F	
Initial boiling point	255
50% Condensed	
Dry point	256
Specific gravity of liquid at 60/60 F	0.7872
at 20/4 C	0.7825
API gravity at 60 F	48.2
Density of liquid at 60 F, lbs/gal	6.56
Vapor pressure at 70 F, psia	
100 F, psia	0.7
Refractive index, 20/D	1.4297
Color, Saybolt	+30
Acidity, distillation residue	netural
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	
Copper corrosion	
Doctor test	
Flash point, approximate, F	60

*Literature values.

Table 2.44: Mixed 1,4-Dimethylcyclohexanes *(4)*

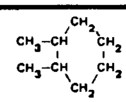
FORMULA	C_8H_{16}
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
1,2-Dimethylcyclopentane	
Normal Heptane	
Methylcyclohexane	
Ethylcyclopentane	
Toluene	
trans-1,4-Dimethylcyclohexane	44.0 } 95.0 min
cis-1,4-Dimethylcyclohexane	54.9 } 95.0 min
Other Dimethylcyclohexanes	1.1
trans-1,2-Dimethylcyclohexane	
cis-1,2-Dimethylcyclohexane	
ortho-Xylene	
Unidentified Impurities	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	250
50% Condensed	252
Dry point	253
Specific gravity of liquid at 60/60 F	0.7784
at 20/4 C	0.7739
API gravity at 60 F	50.3
Density of liquid at 60 F, lbs/gal	6.48
Vapor pressure at 70 F, psia	0.4
100 F, psia	2.0
Refractive index, 20/D	1.4257
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	
Copper corrosion	
Doctor test	negative
Flash point, approximate, F	45 (D 56)

Table 2.45: trans-1,2-Dimethylcyclohexane *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
1,2-Dimethylcyclopentane			
Normal Heptane			
Methylcyclohexane			0.7
Ethylcyclopentane			
Toluene			
trans-1,4-Dimethylcyclohexane			
cis-1,4-Dimethylcyclohexane			
Other Dimethylcyclohexanes	0.02	0.2	0.2
trans-1,2-Dimethylcyclohexane	99.90	99.6	96.9 95.0 min
cis-1,2-Dimethylcyclohexane	0.08	0.2	2.0
ortho-Xylene			0.2
Unidentified Impurities			
Purity by freezing point, mol %	99.73	99.3 99.0 min	
Freezing point, F	−126.75*		
Boiling point, F	254.15*		
Distillation range, F			
Initial boiling point			252
50% Condensed			
Dry point			253
Specific gravity of liquid at 60/60 F	0.7803*	0.780	0.780
at 20/4 C	0.77601*	0.776	0.776
API gravity at 60 F		49.9	49.9
Density of liquid at 60 F, lbs/gal		6.49	6.49
Vapor pressure at 70 F, psia			
100 F, psia	0.71*	0.7	0.7
Refractive index, 20/D	1.42695*	1.427	1.427
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent		0.005	0.005
Copper corrosion		1	1
Doctor test		negative	negative
Flash point, approximate, F		51 (D 56)	51 (D 56)

*Literature values.

Table 2.46: cis-1,2-Dimethylcyclohexane *(4)*

FORMULA		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
Methylcyclohexane		
trans-1,2-Dimethylcyclohexane	0.03	0.1
cis-1,2-Dimethylcyclohexane	99.96	99.7
Ethylcyclohexane		
Ethylbenzene		
Xylenes	0.01	0.2
Isopropylbenzene		
Isopropylcyclohexane		
Unidentified		
Purity by freezing point, mol %	99.91	99.5 99.0 min
Freezing point, F	−58.04*	
Boiling point, F	265.51*	
Distillation range, F		
Initial boiling point		

(continued)

Table 2.46: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE
Dry point		
Specific gravity of liquid at 60/60 F	0.8006*	0.801
at 20/4 C	0.79627*	0.796
API gravity at 60 F		45.2
Density of liquid at 60 F, lbs/gal		6.67
Vapor pressure at 70 F, psia	0.23*	0.2
100 F, psia	0.54*	0.5
Refractive index, 20/D	1.43596*	1.436
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Sulfur content, weight percent		0.005
Copper corrosion		1
Doctor test		negative
Flash point, approximate, F		60 (D 56)

*Literature values.

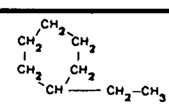
Table 2.47: Mixed 1,2-Dimethylcyclohexane *(4)*

FORMULA	C_8H_{16}
PROPERTIES	**PURE GRADE**
Composition, weight percent	
Methylcyclohexane	trace
trans-1,2-Dimethylcyclohexane	34 } 99.0 min
cis-1,2-Dimethylcyclohexane	66 } 99.0 min
Ethylcyclohexane	
Ethylbenzene	
Xylenes	trace
Isopropylbenzene	
Isopropylcyclohexane	
Unidentified	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	260

PROPERTIES	PURE GRADE
Distillation range, F	
Initial boiling point	
Dry point	
Specific gravity of liquid at 60/60 F	0.792
at 20/4 C	0.789
API gravity at 60 F	47.2
Density of liquid at 60 F, lbs/gal	6.59
Vapor pressure at 70 F, psia	
100 F, psia	0.6*
Refractive index, 20/D	1.432
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Sulfur content, weight percent	0.005
Copper corrosion	1
Doctor test	negative
Flash point, approximate, F	55 (D 56)

*Literature values.

Table 2.48: Ethylcyclohexane *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Methylcyclohexane			
trans-1,2-Dimethylcyclohexane			
cis-1,2-Dimethylcyclohexane			2.0
Ethylcyclohexane	99.98	99.5	96.9
Ethylbenzene	0.02	0.4	0.8
Xylenes			
Isopropylbenzene			
Isopropylcyclohexane			
Unidentified	trace	0.1	0.3

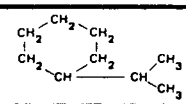
(continued)

Table 2.48: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Purity by freezing point, mol %	99.66	99.19 99.0 min	96.06 95.0 min
Freezing point, F	−168.38*		
Boiling point, F	269.21*		
Distillation range, F			
Initial boiling point			266
Dry point			269
Specific gravity of liquid at 60/60 F	0.7922*	0.793	0.793
at 20/4 C	0.78792*	0.788	0.788
API gravity at 60 F		46.9	46.9
Density of liquid at 60 F, lbs/gal		6.60	6.60
Vapor pressure at 70 F, psia			
100 F, psia	0.48*	0.5	0.5
Refractive index, 20/D	1.43304*	1.433	1.433
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent			
Copper corrosion			
Doctor test			
Flash point, approximate, F	66	66	66

*Literature values.

Table 2.49: Isopropylcyclohexane *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Methylcyclohexane			
trans-1,2-Dimethylcyclohexane			
cis-1,2-Dimethylcyclohexane			
Ethylcyclohexane			
Ethylbenzene			
Xylenes		0.02	
Isopropylbenzene	0.03	0.02	0.79
Isopropylcyclohexane	99.97	99.90	99.05
Unidentified		0.06	0.16
Purity by freezing point, mol %	99.67	99.4 99.0 min	95.2 95.0 min
Freezing point, F	−128.9*		
Boiling point, F	310.57*		
Distillation range, F			
Initial boiling point			307
Dry point			310
Specific gravity of liquid at 60/60 F	0.8064*	0.807	0.807
at 20/4 C	0.8024*	0.803	0.803
API gravity at 60 F		43.8	43.8
Density of liquid at 60 F, lbs/gal		6.72	6.72
Vapor pressure at 70 F, psia			
100 F, psia			
Refractive index, 20/D	1.44087*	1.441	1.441
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Sulfur content, weight percent			
Copper corrosion			
Doctor test			
Flash point, approximate, F	96	96	96

*Literature values.

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Table 2.50: Ethylene *(4)*

FORMULA	$CH_2=CH_2$	
PROPERTIES	**RESEARCH GRADE**	**99.8% GRADE**
Composition, weight percent		
Propane		
Propylene		
Ethylene	99.97	99.88 99.8 min
Ethane	0.01	0.04
Methane	0.02	0.08
Carbon Dioxide, ppm		1 15 max
Acetylene, ppm (liquid)		1 5 max
Carbonyl, ppm (liquid)		
Carbon Monoxide, ppm		1 5 max
Oxygen, ppm		20
Hydrogen, ppm		1 5 max
Freezing point, triple point, F	−272.47*	
Boiling point, F	−154.68*	
Specific gravity of liquid at 60/60 F		
at 20/4 C		
API gravity at 60 F		
Density of liquid at 60 F, lbs/gal		
Vapor pressure at 70 F, psia		
100 F, psia		
130 F, psia		
Sulfur content, ppm		3 10 max
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	0.9740*	
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	13.4524*	
Critical temperature, F	49.82*	
Critical pressure, psia	742.1*	
Density of real gas at 60 F and 14.7 psia, lbs/cu ft		0.0743
Flash point, approximate, F		−213
Flammability limits, volume % in air		
Lower	2.7*	
Higher	34*	
Heating value for ideal gas at 60 F and 14.7 psia, BTU/cu ft, dry basis	1599*	

*Literature values.

Table 2.51: Propylene *(4)*

FORMULA	$CH_2=CH-CH_3$	
PROPERTIES	**RESEARCH GRADE**	**POLYMERIZATION GRADE**
Composition, weight percent		
Propane	0.01	0.5
Propylene	99.99	99.5 99.0 min
Ethylene		
Ethane		trace
Methane		
Carbon Dioxide, ppm		
Acetylene, ppm (liquid)		10
Carbonyl, ppm (liquid)		20
Carbon Monoxide, ppm		
Oxygen, ppm		
Hydrogen, ppm		
Freezing point, triple point, F	−301.45*	
Boiling point, F	−53.86*	
Specific gravity of liquid at 60/60 F	0.5220*	0.522
at 20/4 C	0.5139*	0.514
API gravity at 60 F		139.6
Density of liquid at 60 F, lbs/gal		4.35
Vapor pressure at 70 F, psia		151
100 F, psia		242
130 F, psia		328
Sulfur content, ppm		4
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	1.4765*	
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	8.8736*	
Critical temperature, F	197.4*	
Critical pressure, psia	667*	
Density of real gas at 60 F and 14.7 psia, lbs/cu ft		0.1127
Flash point, approximate, F		−162
Flammability limits, volume % in air		
Lower	2.0*	
Higher	10*	
Heating value for ideal gas at 60 F and 14.7 psia, BTU/cu ft, dry basis	2334*	

*Literature values.

Table 2.52: Isobutylene *(4)*

FORMULA	$CH_3-C(CH_3)=CH_2$	
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
Isobutane	0.06	0.1
Isobutylene	99.81	99.3 99.0 min
Butene-1	0.09	0.4
Butadiene-1,3		
Normal Butane	0.04	0.2
Butene-2	trace	trace
Acetylene (as Methylacetylene) ppm, wt.		
Water, ppm, weight		177
Carbonyl (as Acetaldehyde) ppm, weight		nil
Propadiene, ppm, weight		

PROPERTIES	RESEARCH GRADE	PURE GRADE
Freezing point, F	−220.63*	
Boiling point, F	19.58*	
Specific gravity of liquid at 60/60 F	0.6004*	0.600
at 20/4 C	0.5942*	
API gravity at 60 F		104.3
Density of liquid at 60 F, lbs/gal		4.99
Vapor pressure at 70 F, psia		
100 F, psia		63.4
130 F, psia		
Sulfur content, ppm		8
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)		1.997
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb		6.561
Flash point, approximate, F		−105
Flammability limits, volume % in air		
Lower		
Higher		

*Literature values.

Table 2.53: Butene-1 *(4)*

FORMULA	$CH_3–CH_2–CH=CH_2$	
PROPERTIES	**RESEARCH GRADE**	**POLYMERIZATION GRADE**
Composition, weight percent		
Isobutane		0.1
Isobutylene	0.2	0.3
Butene-1	99.8	99.4 99.0 min
Butadiene-1,3		trace
Normal Butane		0.2
Butene-2		trace
Acetylene (as Methylacetylene) ppm, wt.		15 25 max
Water, ppm, weight		
Carbonyl (as Acetaldehyde) ppm, weight		10 20 max
Propadiene, ppm, weight		4
Freezing point, F	−301.63*	
Boiling point, F	20.73*	
Specific gravity of liquid at 60/60 F	0.6013*	0.601
at 20/4 C	0.5951*	
API gravity at 60 F		103.9
Density of liquid at 60 F, lbs/gal		5.00
Vapor pressure at 70 F, psia		37.5
100 F, psia		67.5 (105F)
130 F, psia		99.7
Sulfur content, ppm		1 10 max
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb		
Flash point, approximate, F		-112
Flammability limits, volume % in air		
Lower	1.6*	
Higher	9.3*	

*Literature values.

Table 2.54: trans-Butene-2 *(4)*

FORMULA	$CH_3–C(H)=C(H)–CH_3$ (H above first C, H below second C)		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Butene-1	0.03		trace
Normal Butane	0.07	0.2	1.3
trans-Butene-2	99.80	99.6	97.7 95.0 min
cis-Butene-2	0.10	0.2	1.0
Purity by freezing point, mol %	99.76	99.2 99.0 min	
Freezing point, F	−157.99*		
Boiling point, F	33.58*		
Specific gravity of liquid at 60/60 F	0.6100*	0.610	0.609
at 20/4 C	0.6042*		
API gravity at 60 F		100.5	100.8
Density of liquid at 60 F, lbs/gal		5.07	5.07
Vapor pressure at 70 F, psia	29.94*	29.9	30
105 F, psia		52.2	52
130 F, psia		76.4	76
Flash point, approximate, F		−100	−100

*Literature values.

Table 2.55: cis-Butene-2 *(4)*

FORMULA	$CH_3–C(H)=C(H)–CH_3$ (H above both C)		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Butene-1			
Normal Butane			
trans-Butene-2	0.03	0.5	4.3
cis-Butene-2	99.97	99.5	95.7 95.0 min

(continued)

Table 2.55: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Purity by freezing point, mol %	99.92	99.4 99.0 min	
Freezing point, F	−218.04*		
Boiling point, F	38.70*		
Specific gravity of liquid at 60/60 F	0.6271*	0.627	0.632
at 20/4 C	0.6213*		
API gravity at 60 F		94.2	92.4
Density of liquid at 60 F, lbs/gal		5.22	5.26
Vapor pressure at 70 F, psia	27.29*	27.3	27.8
105 F, psia		49.8	50.8
130 F, psia		73.2	74.8
Flash point, approximate, F		−100	−100

*Literature values.

Table 2.56: Mixed 2-Butenes *(4)*

FORMULA	$CH_3-CH=CH-CH_3$	
PROPERTIES	PURE GRADE	TECHNICAL GRADE
Composition, weight percent		
Butene-1		0.3
Normal Butane		2.7
trans-Butene-2	45.0 } 99.0 min	52.0 } 95.0 min
cis-Butene-2	55.0	45.0
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F		
Specific gravity of liquid at 60/60 F	0.619	0.618
at 20/4 C	0.615	0.614
API gravity at 60 F	97.1	97.5
Density of liquid at 60 F, lbs/gal	5.15	5.14
Vapor pressure at 70 F, psia	28.0	28.1
105 F, psia	51.0	51.2
130 F, psia	76.5	76.7
Flash point, approximate, F	−95	−100

*Literature values.

Table 2.57: 3-Methylbutene-1 *(4)*

FORMULA	$CH_2=CH-CH(CH_3)-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight percent			
3-Methylbutene-1	99.97	99.8	96.3 95.0 min
2-Methylbutene-1		0.1	2.0
2-Methylbutene-2			
Pentene-1			0.2
Pentenes-2	0.02	0.1	1.0
Isopentane	0.01	trace	0.5
Normal Pentane			

(continued)

Table 2.57: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Purity by freezing point, mol %	99.93	99.4 99.0 min	
Freezing point, F	−271.29*		
Boiling point, F	68.11*		
Distillation range, F			
Initial boiling point			
Dry point			
Specific gravity of liquid at 60/60 F	0.6325*	0.633	0.633
at 20/4 C	0.6272*	0.628	0.628
API gravity at 60 F		91.9	91.9
Density of liquid at 60 F, lbs/gal		5.27	5.27
Vapor pressure at 70 F, psia	15.25*	15.2	15.0
100 F, psia	26.41*	26.4	26.0
130 F, psia			
Refractive index, 20/D	1.3643*	1.364	1.364
Color, Saybolt	+30	+30	+30
Acidity, distillation residue			
Nonvolatile matter, grams/100 ml			
Flash point, approximate, F		−70	−70

*Literature values.

Table 2.58: 2-Methylbutene-1 *(4)*

FORMULA	$CH_2{=}C(CH_3){-}CH_2{-}CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
3-Methylbutene-1		trace	0.3
2-Methylbutene-1	99.99	99.8	97.3 95.0 min
2-Methylbutene-2		trace	0.1
Pentene-1	0.01	0.1	1.9
Pentenes-2		trace	0.2
Isopentane			
Normal Pentane		0.1	0.2
Purity by freezing point, mol %	99.85	99.5 99.0 min	
Freezing point, F	−215.61*		
Boiling point, F	88.09*		
Distillation range, F			
Initial boiling point			87
Dry point			88
Specific gravity of liquid at 60/60 F	0.6557*	0.656	0.656
at 20/4 C	0.6504*	0.650	0.650
API gravity at 60 F		84.2	84.2
Density of liquid at 60 F, lbs/gal		5.46	5.46
Vapor pressure at 70 F, psia	10.21*	10.3	10.3
100 F, psia	18.40*	18.8	18.8
130 F, psia		32.0	32.0
Refractive index, 20/D	1.3778*	1.378	1.378
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		−55	−55

*Literature values.

Table 2.59: Methylbutene-2 *(4)*

FORMULA	$CH_3-\overset{CH_3}{\overset{\vert}{C}}=CH-CH_3$			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**	**COMMERCIAL GRADE**
Composition, weight percent				
3-Methylbutene-1				
2-Methylbutene-1	trace	0.2	0.2	10.3
2-Methylbutene-2	99.99	99.5	97.4 95.0 min	87.8
Pentene-1	trace		0.1	
Pentenes-2	0.01	0.3	2.3	0.8
Isopentane				1.1
Normal Pentane				
Purity by freezing point, mol %	99.78	99.3 99.0 min		
Freezing point, F	−208.78*			
Boiling point, F	101.42*			
Distillation range, F				
Initial boiling point			101	100.7
Dry point			102	101.3
Specific gravity of liquid at 60/60 F	0.6676*	0.668	0.667	0.668
at 20/4 C	0.6623*	0.662	0.662	0.663
API gravity at 60 F		80.3	80.6	
Density of liquid at 60 F, lbs/gal		5.56	5.55	5.56
Vapor pressure at 70 F, psia	7.76*	7.8	7.8	
100 F, psia	14.30*	14.3	14.3	
130 F, psia	24.56*	24.6	24.6	
Refractive index, 20/D	1.3874*	1.387	1.387	1.387
Color, Saybolt	+30	+30	+30	
Acidity, distillation residue		neutral	neutral	
Nonvolatile matter, grams/100 ml		0.0005	0.0005	
Flash point, approximate, F		−50	−50	−60

*Literature values.

Table 2.60: Pentene-1 *(4)*

FORMULA	$CH_2=CH-CH_2-CH_2-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Isopentane		trace	0.1
Pentene-1	99.9	99.4 99.0 min	97.0 95.0 min
2-Methylbutene-1		0.3	1.4
Normal Pentane		0.1	0.5
trans-Pentene-2	0.1	0.2	0.5
cis-Pentene-2			
2-Methylbutene-2		trace	0.5
Purity by freezing point, mol %			
Freezing point, F	−265.40*		
Boiling point, F	85.94*		
Distillation range, F			
Initial boiling point			85
Dry Point			87
Specific gravity of liquid at 60/60 F	0.6457*	0.646	0.646
at 20/4 C	0.64050*	0.641	0.641
API gravity at 60 F		87.5	87.5
Density of liquid at 60 F, lbs/gal		5.38	5.38
Vapor pressure at 70 F, psia	10.70*	10.7	10.6
100 F, psia	19.12*	19.1	19.0
130 F, psia		33.0	32.8
Refractive index, 20/D	1.37148*	1.372	1.372
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		−60	−60
Flammability limits, volume % in air			
Lower	1.4*		
Higher	8.7*		

* Literature values.

Table 2.61: cis-Pentene-2 *(4)*

FORMULA	$CH_3-\overset{H}{C}=\overset{H}{C}-CH_2-CH_3$	
PROPERTIES	**RESEARCH GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
Isopentane		
Pentene-1		
2-Methylbutene-1		
Normal Pentane		
trans-Pentene-2	0.1	3.2
cis-Pentene-2	99.9	96.8 95.0 min
2-Methylbutene-2		
Purity by freezing point, mol %	99.8	
Freezing point, F	−240.50*	
Boiling point, F	98.50*	
Distillation range, F		
Initial boiling point		
Dry Point		
Specific gravity of liquid at 60/60 F	0.6608*	0.660
at 20/4 C	0.6556*	0.655
API gravity at 60 F		82.9
Density of liquid at 60 F, lbs/gal		5.49
Vapor pressure at 70 F, psia	8.24*	8.3
100 F, psia	15.12	15.1
130 F, psia	25.84*	26.6
Refractive index, 20/D	1.3830*	1.383
Color, Saybolt		+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Flash point, approximate, F		−50
Flammability limits, volume % in air		
Lower		
Higher		

* Literature values.

Table 2.62: trans-Pentene-2 *(4)*

FORMULA	$CH_3-\overset{H}{C}=\underset{H}{C}-CH_2-CH_3$
PROPERTIES	**RESEARCH GRADE**
Composition, weight percent	
Isopentane	
Pentene-1	
2-Methylbutene-1	
Normal Pentane	0.02
trans-Pentene-2	99.63
cis-Pentene-2	0.35
2-Methylbutene-2	
Purity by freezing point, mol %	99.53
Freezing point, F	−220.44*
Boiling point, F	97.44*
Distillation range, F	
Initial boiling point	
Dry Point	
Specific gravity of liquid at 60/60 F	0.6533*
at 20/4 C	0.6482*
API gravity at 60 F	
Density of liquid at 60 F, lbs/gal	5.447*
Vapor pressure at 70 F, psia	10.2*
100 F, psia	15.4*
130 F, psia	26.3*
Refractive index, 20/D	1.3793*
Color, Saybolt	+30
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	
Flash point, approximate, F	
Flammability limits, volume % in air	
Lower	
Higher	

* Literature values.

Table 2.63: Mixed 2-Pentenes *(4)*

FORMULA	$CH_3-CH=CH-CH_2-CH_3$	
PROPERTIES	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
Isopentane		
Pentene-1	0.1	0.1
2-Methylbutene-1	0.1	0.3
Normal Pentane	0.1	1.6
trans-Pentene-2	46.6 } 99.0 min	48.8 } 95.0 min
cis-Pentene-2	53.0 }	48.2 }
2-Methylbutene-2	0.1	1.0
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F		
Distillation range, F		
Initial boiling point		97
Dry Point		99
Specific gravity of liquid at 60/60 F	0.656	0.658
at 20/4 C	0.652	0.654
API gravity at 60 F	84.2	83.5
Density of liquid at 60 F, lbs/gal	5.46	5.48
Vapor pressure at 70 F, psia	8.4	8.3
100 F, psia	15.4	15.2
130 F, psia	27.0	26.7
Refractive index, 20/D	1.380	1.381
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml	0.0005	0.0005
Flash point, approximate, F	−50	−50
Flammability limits, volume % in air		
Lower		
Higher		

Table 2.64: 3,3-Dimethylbutene-1 *(4)*

Neohexene

FORMULA	$CH_2=CH-C(CH_3)_2-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
3,3-Dimethylbutene-1	98.9
2,3-Dimethylbutane	
4-Methylpentene-1	
3-Methylpentene-1	
2,3-Dimethylbutene-1	
2,3-Dimethylbutene-2	
cis-4-Methylpentene-2	
trans-4-Methylpentene-2	
2-Methylpentene-2	
Other Olefins	1.1
Purity by freezing point, mol %	
Freezing point, F	−184.43
Boiling point, F	
Distillation range, F	
Initial boiling point	106
10% Condensed	106
50% Condensed	107
90% Condensed	111
Dry point	114
Specific gravity of liquid at 60/60 F	0.6582
at 20/4 C	0.6533
API gravity at 60 F	83.5
Density of liquid at 60 F, lbs/gal	5.48
Vapor pressure at 70 F, psia	7.2
100 F, psia	14.6
130 F, psia	
Refractive index, 20/D	1.3766
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Doctor test	negative
Flash point, approximate, F	45

*Literature values.

Table 2.65: Mixed 2,3-Dimethylbutenes *(4)*

FORMULA	C_6H_{12}
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
3,3-Dimethylbutene-1	
2,3-Dimethylbutane	2.0
4-Methylpentene-1	
3-Methylpentene-1	
2,3-Dimethylbutene-1	32.0 } 95.0 min
2,3-Dimethylbutene-2	63.9 }
cis-4-Methylpentene-2	
trans-4-Methylpentene-2	
2-Methylpentene-2	2.1
Other Olefins	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	140
10% Condensed	
50% Condensed	
90% Condensed	
Dry point	169
Specific gravity of liquid at 60/60 F	0.703
at 20/4 C	
API gravity at 60 F	69.8
Density of liquid at 60 F, lbs/gal	5.85
Vapor pressure at 70 F, psia	
100 F, psia	5.7
130 F, psia	
Refractive index, 20/D	
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Doctor test	
Flash point, approximate, F	−35

*Literature values.

Table 2.66: 4-Methylpentene-1 *(4)*

FORMULA	$CH_2=CH-CH_2-CH(CH_3)-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
3,3-Dimethylbutene-1			
2,3-Dimethylbutane			
4-Methylpentene-1	99.94	99.6	99.1
3-Methylpentene-1	0.02	0.1	0.2
2,3-Dimethylbutene-1			
2,3-Dimethylbutene-2			
cis-4-Methylpentene-2	0.02	0.3	0.6
trans-4-Methylpentene-2	0.02		0.1
2-Methylpentene-2			
Other Olefins			
Purity by freezing point, mol %	99.81	99.3 99.0 min	97.5 95.0 min
Freezing point, F		−244.53*	
Boiling point, F		128.96*	
Distillation range, F			
Initial boiling point			129
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			130
Specific gravity of liquid at 60/60 F	0.6686*	0.669	0.669
at 20/4 C	0.66370*	0.664	0.664

(continued)

Table 2.66: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
API gravity at 60 F		80.0	80.0
Density of liquid at 60 F, lbs/gal		5.57	5.57
Vapor pressure at 70 F, psia	4.48*	4.5	4.5
100 F, psia	8.50*	8.5	8.5
130 F, psia	14.97*	15.0	15.0
Refractive index, 20/D	1.38267*	1.383	1.383
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Doctor test			
Flash point, approximate, F		−25	−25

*Literature values.

Table 2.67: cis-4-Methylpentene-2 *(4)*

FORMULA	$CH_3-\overset{H}{C}=\overset{H}{C}-\overset{CH_3}{CH}-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
3,3-Dimethylbutene-1			
2,3-Dimethylbutane			
4-Methylpentene-1	0.06	0.1	0.2
3-Methylpentene-1			
2,3-Dimethylbutene-1			
2,3-Dimethylbutene-2			
cis-4-Methylpentene-2	99.87	99.8	97.1
trans-4-Methylpentene-2	0.07	0.1	2.4
2-Methylpentene-2			
Other Olefins			0.3
Purity by freezing point, mol %	99.71	99.52 99.0 min	96.2 95.0 min
Freezing point, F	−209.97*		
Boiling point, F	133.50*		
Distillation range, F			
Initial boiling point			130
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			133
Specific gravity of liquid at 60/60 F	0.6741*	0.674	0.674
at 20/4 C	0.66918*	0.669	0.669
API gravity at 60 F		78.4	78.4
Density of liquid at 60 F, lbs/gal		5.61	5.61
Vapor pressure at 70 F, psia	4.01*	4.0	4.0
100 F, psia	7.73*	7.7	7.7
130 F, psia	13.80*	13.8	13.8
Refractive index, 20/D	1.38793*	1.388	1.388
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Doctor test			
Flash point, approximate, F		−25	−25

*Literature values.

Table 2.68: trans-4-Methylpentene-2 *(4)*

FORMULA	$CH_3-\overset{H}{C}=\underset{H}{C}-\overset{CH_3}{CH}-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
4-Methylpentene-1			
cis-4-Methylpentene-2	trace	0.1	0.6
trans-4-Methylpentene-2	99.98	99.9	96.5
2-Methylpentene-1			
2-Methylpentene-2			
Isoolefins	0.02	trace	2.9
Purity by freezing point, mol %	99.94	99.2 99.0 min	95.6 95.0 min
Freezing point, F	−221.46*		
Boiling point, F	137.50*		
Distillation range, F			
Initial boiling point			137.1
Dry point			137.8
Specific gravity of liquid at 60/60F	0.6736*	0.673	0.674
at 20/4 C	0.66862*	0.669	0.670
API gravity at 60 F		78.7	78.4
Density of liquid at 60 F, lbs/gal		5.60	5.61
Vapor pressure at 70 F, psia	3.66*	3.7	3.7
100 F, psia	7.12*	7.1	7.1
130 F, psia	12.82*	12.8	12.8
Refractive index, 20/D	1.38878*	1.389	1.389
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		−20	−20

*Literature values.

Table 2.69: Mixed 4-Methyl-2-Pentenes *(4)*

FORMULA	$CH_3-CH=CH-\overset{CH_3}{CH}-CH_3$	
PROPERTIES	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
4-Methylpentene-1	0.1	2.8
cis-4-Methylpentene-2	76.5 } 99.0 min	76.2 } 95.0 min
trans-4-Methylpentene-2	23.4	20.8
2-Methylpentene-1		
2-Methylpentene-2		
Isoolefins		0.2
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F	135.0	
Distillation range, F		
Initial boiling point		136.0
Dry point		137.2
Specific gravity of liquid at 60/60F	0.673	0.673
at 20/4 C	0.669	0.669
API gravity at 60 F	78.8	78.8
Density of liquid at 60 F, lbs/gal	5.60	5.60
Vapor pressure at 70 F, psia	3.8	3.8
100 F, psia	7.5	7.5
130 F, psia	13.0	13.0
Refractive index, 20/D	1.388	1.388
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml	0.0005	0.0005
Flash point, approximate, F	−20	−20

Table 2.70: 2-Methylpentene-1 *(4)*

FORMULA	$CH_2=C(CH_3)-CH_2-CH_2-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
4-Methylpentene-1			0.6
cis-4-Methylpentene-2			0.5
trans-4-Methylpentene-2		0.1	0.2
2-Methylpentene-1	99.90	99.8	95.8 95.0 min
2-Methylpentene-2			
Isoolefins	0.10	0.1	2.9
Purity by freezing point, mol %	99.84	99.65 99.0 min	
Freezing point, F	−212.30*		
Boiling point, F	143.80*		
Distillation range, F			
Initial boiling point			142.8
Dry point			143.6
Specific gravity of liquid at 60/60F	0.6848*	0.685	0.685
at 20/4 C	0.67987*	0.680	0.680
API gravity at 60 F		75.4	75.4
Density of liquid at 60 F, lbs/gal		5.69	5.69
Vapor pressure at 70 F, psia	3.20*	3.2	3.2
100 F, psia	6.30*	6.3	6.3
130 F, psia	11.43*	11.4	11.4
Refractive index, 20/D	1.39200*	1.392	1.392
Color, Saybolt		+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		−15	−15

*Literature values.

Table 2.71: 2-Methylpentene-2 *(4)*

FORMULA	$CH_3-C(CH_3)=CH-CH_2-CH_3$	
PROPERTIES	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
4-Methylpentene-1		
cis-4-Methylpentene-2		
trans-4-Methylpentene-2		
2-Methylpentene-1	0.1	1.6
2-Methylpentene-2	99.8	96.0 95.0 min
Isoolefins	0.1	2.4
Purity by freezing point, mol %		
Freezing point, F	−211.13*	
Boiling point, F	153.15*	
Distillation range, F		
Initial boiling point		152
Dry point		158
Specific gravity of liquid at 60/60F	0.6913*	0.692
at 20/4 C	0.68650*	0.687
API gravity at 60 F		73.1
Density of liquid at 60 F, lbs/gal		5.76
Vapor pressure at 70 F, psia	2.57*	2.6
100 F, psia	5.17*	5.1
130 F, psia	9.58*	9.6
Refractive index, 20/D	1.40030*	1.400
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml	0.0005	0.0005
Flash point, approximate, F	−10	−10

*Literature values.

Table 2.72: Hexene-1 *(4)*

FORMULA	$CH_2=CH-CH_2-CH_2-CH_2-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Hexene-1	99.98	99.7	96.8
trans-Hexene-2 cis-Hexene-2	} 0.02	} 0.2	} 0.1
Hexenes-3			0.3
Normal Hexane		0.1	1.2
Isoolefins			1.6
Heptene-1			
trans-Heptene-3			
cis-Heptene-3			
trans-Heptene-2			
cis-Heptene-2			
Purity by freezing point, mol %	99.97	99.14 99.0 min	95.8 95.0 min
Freezing point, F	−219.67*		
Boiling point, F	146.27*		
Distillation range, F			
Initial boiling point			146.2
Dry point			146.3
Specific gravity of liquid at 60/60 F	0.6780*	0.678	0.677
at 20/4 C	0.67317*	0.673	0.674
API gravity at 60 F		77.2	77.5
Density of liquid at 60 F, lbs/gal		5.64	5.64
Vapor pressure at 70 F, psia	3.04*	3.0	3.0
100 F, psia	6.01*	6.0	6.0
130 F, psia	10.93*	10.9	10.9
Refractive index, 20/D	1.38788*	1.388	1.388
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		−15	−15

*Literature values.

Table 2.73: cis-Hexene-2 *(4)*

FORMULA	$CH_3-CH=CH-CH_2-CH_2-CH_3$ (H, H on the double-bonded carbons, cis)
PROPERTIES	**RESEARCH GRADE**
Composition, weight percent	
Hexene-1	0.1
trans-Hexene-2	0.2
cis-Hexene-2	99.6
Hexenes-3	
Normal Hexane	
Isoolefins	0.1
Heptene-1	
trans-Heptene-3	
cis-Heptene-3	
trans-Heptene-2	
cis-Heptene-2	
Purity by freezing point, mol %	99.28
Freezing point, F	−222.04*
Boiling point, F	156.00*
Distillation range, F	
Initial boiling point	
Dry point	
Specific gravity of liquid at 60/60 F	0.6920*
at 20/4 C	0.68720*
API gravity at 60 F	
Density of liquid at 60 F, lbs/gal	5.760*
Vapor pressure at 70 F, psia	2.4*
100 F, psia	4.9*
130 F, psia	9.1*
Refractive index, 20/D	1.39761*
Color, Saybolt	+30
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	
Flash point, approximate, F	

*Literature values.

Table 2.74: Mixed 2-Hexenes *(4)*

FORMULA	$CH_3-CH=CH-CH_2-CH_2-CH_3$	
PROPERTIES	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
Hexene-1	trace	0.3
trans-Hexene-2	35.6 } 99.0 min	34.1 } 95.0 min
cis-Hexene-2	63.6	63.5
Hexenes-3	0.8	2.1
Normal Hexane		
Isoolefins		
Heptene-1		
trans-Heptene-3		
cis-Heptene-3		
trans-Heptene-2		
cis-Heptene-2		
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F		
Distillation range, F		
Initial boiling point	155.0	155.0
Dry point	155.1	155.1
Specific gravity of liquid at 60/60 F	0.684	0.686
at 20/4 C		
API gravity at 60 F	75.4	74.8
Density of liquid at 60 F, lbs/gal	5.69	5.71
Vapor pressure at 70 F, psia	2.4	2.4
100 F, psia	5.0	5.0
130 F, psia	9.2	9.2
Refractive index, 20/D	1.396	1.396
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml	0.0005	0.0005
Flash point, approximate, F	−5	−5

Table 2.75: Mixed 2- and 3-Hexenes *(4)*

FORMULA	C_6H_{12}
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Hexene-1	2.3
trans-Hexene-2	71.1 } 95.0 min
cis-Hexene-2	15.8 }
Hexenes-3	10.8 }
Normal Hexane	
Isoolefins	
Heptene-1	
trans-Heptene-3	
cis-Heptene-3	
trans-Heptene-2	
cis-Heptene-2	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	152.2
Dry point	155.4
Specific gravity of liquid at 60/60 F	0.685
at 20/4 C	
API gravity at 60 F	75.1
Density of liquid at 60 F, lbs/gal	5.70
Vapor pressure at 70 F, psia	2.5
100 F, psia	5.2
130 F, psia	9.6
Refractive index, 20/D	1.396
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Flash point, approximate, F	−10

Table 2.76: Heptene-1 *(4)*

FORMULA	$CH_2=CH-(CH_2)_4-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Hexene-1	
trans-Hexene-2	
cis-Hexene-2	
Hexenes-3	
Normal Hexane	
Isoolefins	1.3
Heptene-1	97.6
trans-Heptene-3	0.5
cis-Heptene-3	0.5
trans-Heptene-2	0.1
cis-Heptene-2	
Purity by freezing point, mol %	95.4 95.0 min
Freezing point, F	−183.0
Boiling point, F	
Distillation range, F	
Initial boiling point	199
Dry point	202
Specific gravity of liquid at 60/60 F	0.7032
at 20/4 C	0.6982
API gravity at 60 F	70.0
Density of liquid at 60 F, lbs/gal	5.85
Vapor pressure at 70 F, psia	0.9
100 F, psia	2.0
130 F, psia	3.9
Refractive index, 20/D	1.4003
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	
Flash point, approximate, F	25 (D 56)

Table 2.77: cis-Heptene-2 *(4)*

FORMULA	$CH_3-CH=CH-(CH_2)_3-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Hexene-1	
trans-Hexene-2	
cis-Hexene-2	
Hexenes-3	
Normal Hexane	
Isoolefins	
Heptene-1	
trans-Heptene-3	
cis-Heptene-3	
trans-Heptene-2	4.0
cis-Heptene-2	96.0 95.0 min
Freezing point, F	
Boiling point, F	209.3
Distillation range, F	
Initial boiling point	
Dry point	
Specific gravity of liquid at 60/60 F	0.717
at 20/4 C	
API gravity at 60 F	67.3
Density of liquid at 60 F, lbs/gal	5.94
Vapor pressure at 70 F, psia	
100 F, psia	
130 F, psia	
Refractive index, 20/D	1.406
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Flash point, approximate, F	0

Table 2.78: Mixed 2-Heptenes *(4)*

FORMULA	$CH_3-CH=CH-(CH_2)_3-CH_3$	
PROPERTIES	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
Heptene-1	trace	1.2
trans-Heptene-3	} 0.5	} 1.4
cis-Heptene-3		
trans-Heptene-2	35.0 } 99.0 min	52.1 } 95.0 min
cis-Heptene-2	64.5	45.0
2,4,4-Trimethylpentene-1		
2,4,4-Trimethylpentene-2		
2,3,3-Trimethylpentene-1		
Isoolefins	trace	0.3
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F		
Distillation range, F		
Initial boiling point	208.4	208.6
10% Condensed		
50% Condensed		
90% Condensed		
Dry point	212.0	217.1
Specific gravity of liquid at 60/60 F	0.711	0.709
at 20/4 C		
API gravity at 60 F	67.5	68.0
Density of liquid at 60 F, lbs/gal	5.92	5.91
Vapor pressure at 100 F, psia		
Refractive index, 20/D	1.406	1.405
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml	0.0005	0.0005
Bromine number		
Kauri Butanol value		
Copper corrosion		
Doctor test		
Flash point, approximate, F	28	28

Table 2.79: Mixed 3-Heptenes *(4)*

FORMULA	$CH_3-CH_2-CH=CH-(CH_2)_2-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Heptene-1	2.0
trans-Heptene-3	66.5 } 95.0 min
cis-Heptene-3	29.3
trans-Heptene-2	0.5
cis-Heptene-2	1.7
2,4,4-Trimethylpentene-1	
2,4,4-Trimethylpentene-2	
2,3,3-Trimethylpentene-1	
Isoolefins	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	204.0
10% Condensed	
50% Condensed	
90% Condensed	
Dry point	204.4
Specific gravity of liquid at 60/60 F	0.705
at 20/4 C	
API gravity at 60 F	69.2
Density of liquid at 60 F, lbs/gal	5.87
Vapor pressure at 100 F, psia	
Refractive index, 20/D	1.405
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Bromine number	
Kauri Butanol value	
Copper corrosion	
Doctor test	
Flash point, approximate, F	21

Table 2.80: 2,4,4-Trimethylpentene-1 *(4)*

α-Diisobutylene

FORMULA	$CH_2=C(CH_3)-CH_2-C(CH_3)_2-CH_3$		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Heptene-1			
trans-Heptene-3			
cis-Heptene-3			
trans-Heptene-2			
cis-Heptene-2			
2,4,4-Trimethylpentene-1	99.86	99.39	98.7
2,4,4-Trimethylpentene-2	0.05	0.08	0.1
2,3,3-Trimethylpentene-1			
Isoolefins	0.09	0.53	1.2
Purity by freezing point, mol %	99.58	99.0 99.0 min	97.6 95.0 min
Freezing point, F	−136.26*		
Boiling point, F	214.59*		

(continued)

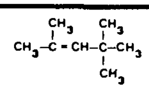
Table 2.80: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Distillation range, F			
Initial boiling point			214.3
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			214.6
Specific gravity of liquid at 60/60 F	0.7194*	0.719	0.720
at 20/4 C	0.7150*	0.715	0.716
API gravity at 60 F		65.3	65.0
Density of liquid at 60 F, lbs/gal		5.98	5.99
Vapor pressure at 100 F, psia		1.6	1.6
Refractive index, 20/D	1.4086*	1.409	1.409
Color, Saybolt		+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Bromine number			
Kauri Butanol value			
Copper corrosion			
Doctor test			
Flash point, approximate, F		< 20 (Est.)	< 20 (Est.)

*Literature values.

Table 2.81: 2,4,4-Trimethylpentene-2 *(4)*

β-Diisobutylene



FORMULA	(see structure above)
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Heptene-1	
trans-Heptene-3	
cis-Heptene-3	
trans-Heptene-2	
cis-Heptene-2	
2,4,4-Trimethylpentene-1	1.9
2,4,4-Trimethylpentene-2	97.1
2,3,3-Trimethylpentene-1	
Isoolefins	1.0
Purity by freezing point, mol %	95.1 95.0 min
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	219
10% Condensed	
50% Condensed	
90% Condensed	
Dry point	230
Specific gravity of liquid at 60/60 F	0.724
at 20/4 C	
API gravity at 60 F	64.0
Density of liquid at 60 F, lbs/gal	6.03
Vapor pressure at 100 F, psia	1.5
Refractive index, 20/D	1.416
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Bromine number	
Kauri Butanol value	
Copper corrosion	
Doctor test	
Flash point, approximate, F	35 (D 1310)

Table 2.82: Mixed Diisobutylenes *(4)*

FORMULA	C_8H_{16}
PROPERTIES	**90% GRADE**
Composition, weight percent	
Heptene-1	
trans-Heptene-3	
cis-Heptene-3	
trans-Heptene-2	
cis-Heptene-2	
2,4,4-Trimethylpentene-1	73.2
2,4,4-Trimethylpentene-2	17.0
2,3,3-Trimethylpentene-1	2.9
Isoolefins	6.9
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	216 200 min
10% Condensed	217
50% Condensed	218
90% Condensed	220
Dry point	224 260 max
Specific gravity of liquid at 60/60 F	0.723
at 20/4 C	
API gravity at 60 F	64.2
Density of liquid at 60 F, lbs/gal	6.02
Vapor pressure at 100 F, psia	2.0
Refractive index, 20/D	
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Bromine number	140.3 130 min
Kauri Butanol value	38.3
Copper corrosion	1 1 max
Doctor test	neg. neg.
Flash point, approximate, F	35 (Est.)

Table 2.83: Octene-1 *(4)*

FORMULA	$CH_2 = CH-(CH_2)_5-CH_3$		
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight percent			
Octene-1	99.95	99.8	98.0
trans-Octene-2			
cis-Octene-2			
mixed-Octenes-3	0.01	0.1	0.5
trans-Octene-4			
Nonene-1			
Decene-1			
Isoolefins	0.04	0.1	1.5
Purity by freezing point, mol %	99.73	99.3 99.0 min	95.6 95.0 min
Freezing point, F	−151.12*		
Boiling point, F	250.30*		
Distillation range, F			
Initial boiling point			250.0
Dry point			250.3
Specific gravity of liquid at 60/60 F	0.7194*	0.719	0.718
at 20/4 C	0.71492*	0.715	0.714
API gravity at 60 F		65.3	65.6
Density of liquid at 60 F, lbs/gal		5.98	5.98
Vapor pressure at 70 F, psia	0.23*	0.2	0.2
100 F, psia	0.66*	0.7	0.7
130 F, psia	1.42*	1.4	1.4
Refractive index, 20/D	1.40870*	1.409	1.409
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		70	70

*Literature values.

Table 2.84: cis-Octene-2 *(4)*

FORMULA	$CH_3-\overset{H}{C}=\overset{H}{C}-(CH_2)_4-CH_3$
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
Octene-1	trace
trans-Octene-2	3.6
cis-Octene-2	95.6
mixed-Octenes-3	0.1
trans-Octene-4	0.1
Nonene-1	
Decene-1	
Isoolefins	0.6
Purity by freezing point, mol %	95.0 95.0 min
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	257
Dry point	259
Specific gravity of liquid at 60/60 F	0.728
at 20/4 C	
API gravity at 60 F	62.4
Density of liquid at 60 F, lbs/gal	6.07
Vapor pressure at 70 F, psia	
100 F, psia	
130 F, psia	
Refractive index, 20/D	1.414
Color, Saybolt	
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Flash point, approximate, F	

Table 2.85: Mixed 2-Octenes *(4)*

FORMULA	$CH_3-CH=CH-(CH_2)_4-CH_3$	
PROPERTIES	PURE GRADE	TECHNICAL GRADE
Composition, weight percent		
Octene-1		
trans-Octene-2	50.3 } 99.0 min	61.4 } 95.0 min
cis-Octene-2	49.2 }	36.5 }
mixed-Octenes-3	0.4	1.8
trans-Octene-4		
Nonene-1		
Decene-1		
Isoolefins	0.1	0.3
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F		
Distillation range, F		
Initial boiling point	257.0	256.9
Dry point	258.0	257.5
Specific gravity of liquid at 60/60 F	0.731	0.730
at 20/4 C		
API gravity at 60 F	62.1	62.3
Density of liquid at 60 F, lbs/gal	6.08	6.08
Vapor pressure at 70 F, psia		
100 F, psia		
130 F, psia		
Refractive index, 20/D	1.414	1.414
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml	0.0005	0.0005
Flash point, approximate, F	70	70

Table 2.86: Mixed Octenes *(4)*

FORMULA	C_8H_{16}
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Octene-1	34.6
trans-Octene-2	20.7 } 95.0 min
cis-Octene-2	42.3
mixed-Octenes-3	2.3
trans-Octene-4	
Nonene-1	
Decene-1	
Isoolefins	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	250.0
Dry point	255.0
Specific gravity of liquid at 60/60 F	0.724
at 20/4 C	0.720
API gravity at 60 F	63.8
Density of liquid at 60 F, lbs/gal	6.08
Vapor pressure at 70 F, psia	
100 F, psia	0.5
130 F, psia	
Refractive index, 20/D	1.412
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Flash point, approximate, F	70

Table 2.87: Nonene-1 *(4)*

FORMULA	$CH_2=CH-(CH_2)_6-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Octene-1	0.7
trans-Octene-2	
cis-Octene-2	
mixed-Octenes-3	
trans-Octene-4	
Nonene-1	98.7
Decene-1	
Isoolefins	0.6
Purity by freezing point, mol %	97.1 95.0 min
Freezing point, F	−115.04
Boiling point, F	
Distillation range, F	
Initial boiling point	293
Dry point	297
Specific gravity of liquid at 60/60 F	0.7352
at 20/4 C	0.7306
API gravity at 60 F	61.2
Density of liquid at 60 F, lbs/gal	6.12
Vapor pressure at 70 F, psia	
100 F, psia	
130 F, psia	
Refractive index, 20/D	1.4161
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Flash point, approximate, F	115 (Est.)

Table 2.88: Decene-1 *(4)*

FORMULA	$CH_2=CH-(CH_2)_7-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Octene-1	
trans-Octene-2	
cis-Octene-2	
mixed-Octenes-3	
trans-Octene-4	
Nonene-1	
Decene-1	98.9
Isoolefins	1.1
Purity by freezing point, mol %	96.0 95.0 min
Freezing point, F	−89.25
Boiling point, F	
Distillation range, F	
Initial boiling point	336
Dry point	342
Specific gravity of liquid at 60/60 F	0.7452
at 20/4 C	0.7408
API gravity at 60 F	59.70
Density of liquid at 60 F, lbs/gal	6.16
Vapor pressure at 70 F, psia	
100 F, psia	
130 F, psia	
Refractive index, 20/D	1.4216
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	
Flash point, approximate, F	120 (Est.)

Table 2.89: Undecene-1 *(4)*

FORMULA	$CH_2=CH-(CH_2)_8-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Undecene-1	99.0
Dodecene-1	
Tridecene-1	
Tetradecene-1	
Pentadecene-1	
Hexadecene-1	
Isoolefins	1.0
Purity by freezing point, mol %	95.7 95.0 min
Freezing point, F	−58.27
Distillation range, F	
Initial boiling point	372
Dry point	377
Specific gravity of liquid at 60/60 F	0.7563
at 20/4 C	0.7519
API gravity at 60 F	56.0
Density of liquid at 60 F, lbs/gal	6.31
Refractive index, 20/D	1.4266
Color, Saybolt	+30
Acidity, distillation residue	neutral
Flash point, approximate, F	160

Table 2.90: Dodecene-1 *(4)*

FORMULA	$CH_2=CH-(CH_2)_9-CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Undecene-1	
Dodecene-1	99.2
Tridecene-1	
Tetradecene-1	0.1
Pentadecene-1	
Hexadecene-1	0.2
Isoolefins	0.5
Purity by freezing point, mol %	95.4 95.0 min
Freezing point, F	−33.39
Distillation range, F	
Initial boiling point	410
Dry point	416
Specific gravity of liquid at 60/60 F	0.7624
at 20/4 C	0.7584
API gravity at 60 F	54.10
Density of liquid at 60 F, lbs/gal	6.347
Refractive index, 20/D	1.4300
Color, Saybolt	+30
Acidity, distillation residue	neutral
Flash point, approximate, F	174

Table 2.91: Tridecene-1 *(4)*

FORMULA	$CH_2 = CH - (CH_2)_{10} - CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Undecene-1	
Dodecene-1	0.1
Tridecene-1	99.7
Tetradecene-1	
Pentadecene-1	
Hexadecene-1	
Isoolefins	0.2
Purity by freezing point, mol %	96.6 95.0 min
Freezing point, F	−10.95
Distillation range, F	
Initial boiling point	442.6
Dry point	450.7
Specific gravity of liquid at 60/60 F	0.7704
at 20/4 C	0.7662
API gravity at 60 F	52.7
Density of liquid at 60 F, lbs/gal	6.41
Refractive index, 20/D	1.4336
Color, Saybolt	+30
Acidity, distillation residue	neutral
Flash point, approximate, F	175

Table 2.92: Tetradecene-1 *(4)*

FORMULA	$CH_2 = CH - (CH_2)_{11} - CH_3$
PROPERTIES	**TECHNICAL GRADE**
Composition, weight percent	
Undecene-1	
Dodecene-1	0.1
Tridecene-1	0.3
Tetradecene-1	99.6
Pentadecene-1	trace
Hexadecene-1	
Isoolefins	
Purity by freezing point, mol %	95.5 95.0 min
Freezing point, F	7.05
Distillation range, F	
Initial boiling point	474
Dry point	485
Specific gravity of liquid at 60/60 F	0.7779
at 20/4 C	0.7737
API gravity at 60 F	50.4
Density of liquid at 60 F, lbs/gal	6.48
Refractive index, 20/D	1.4373
Color, Saybolt	+30
Acidity, distillation residue	neutral
Flash point, approximate, F	240

Table 2.93: Butadiene-1,3 *(4)*

FORMULA	$CH_2 = CH-CH = CH_2$		
PROPERTIES	**RESEARCH GRADE**	**SPECIAL PURITY**	**RUBBER GRADE**
Composition, weight percent			
Isobutylene	0.02	0.05	0.1
Butene-1	0.02	0.10	0.2
Butadiene-1,3	99.95	99.70	99.5
trans-Butene-2	0.01	0.10	0.1
Butadiene Dimer		0.05	0.1
Purity by freezing point, mol %	99.89	99.6 99.5 min	99.4 99.0 min
Freezing point, F	−164.05*		
Boiling point, F	24.06*		
Specific gravity of liquid at 60/60 F	0.6272*	0.627	0.627
at 20/4 C	0.6211*	0.621	0.621
API gravity at 60 F		94.2	94.2
Density of liquid at 60 F, lbs/gal		5.22	5.22
Vapor pressure at 70 F, psia		35.6	35.6
100 F, psia		64.0	64.0
130 F, psia		92.2	92.2
Specific gravity of real gas at 60 F and 14.7 psia (Air = 1)	1.9153*		
Specific volume of real gas at 60 F and 14.7 psia, cu ft/lb	6.841*		
Flash point, approximate, F		−105	−105
Flammability limits, volume % in air			
Lower	2.0*		
Higher	11.5*		

*Literature values.

Table 2.94: Isoprene *(4)*

FORMULA	$CH_2=C(CH_3)-CH=CH_2$	
PROPERTIES	**RESEARCH GRADE**	**POLYMERIZATION GRADE**
Composition, weight percent		
2-Methylbutene-1	trace	0.1
2-Methylbutadiene-1,3	99.99	99.8
Pentenes-2	0.01	0.1
2-Methylbutene-2	trace	trace
trans-Pentadiene-1,3		
cis-Pentadiene-1,3		
Cyclopentene		
Cyclooctadiene-1,5		
4-Vinylcyclohexene-1		
1-Methylcyclohexene-1		
3-Methylcyclohexene-1		
4-Methylcyclohexane-1		
Unidentified		
Purity by freezing point, mol %	99.98	99.6 99.0 min
Freezing point, F	−230.71*	
Boiling point, F	93.32*	
Distillation range, F		
Initial boiling point		
10% Condensed		
50% Condensed		
90% Condensed		
Dry point		
Specific gravity of liquid at 60/60 F	0.6861*	0.686
at 20/4 C	0.68095*	0.681
API gravity at 60 F		74.8
Density of Liquid at 60 F, lbs/gal	5.71*	5.71
Vapor pressure at 70 F, psia	9.19*	9.2
100 F, psia	16.67*	16.7
130 F, psia	28.23*	28.2
Refractive index, 20/D	1.42194*	1.422
Color, Saybolt	+30	+30
Acidity, distillation residue		
Nonvolatile matter, grams/100 ml		
Doctor test		
Flash point, approximate, F		−55 (Est.)

*Literature values.

Table 2.95: Piperylene *(4)*

FORMULA	$CH_2=CH-CH=CH-CH_3$
PROPERTIES	**90% GRADE**
Composition, weight percent	
2-Methylbutene-1	
2-Methylbutadiene-1,3	
Pentenes-2	0.1
2-Methybutene-2	0.7
trans-Pentadiene-1,3	57 } 90.0 min**
cis-Pentadiene-1,3	34 }
Cyclopentene	8.2
Cyclooctadiene-1,5	
4-Vinylcyclohexene-1	
1-Methylcyclohexene-1	
3-Methylcyclohexene-1	
4-Methylcyclohexane-1	
Unidentified	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	107
10% Condensed	108
50% Condensed	108
90% Condensed	109
Dry point	113
Specific gravity of liquid at 60/60 F	0.690
at 20/4 C	
API gravity at 60 F	73.5
Density of Liquid at 60 F, lbs/gal	5.75
Vapor pressure at 70 F, psia	
100 F, psia	12.7
130 F, psia	
Refractive index, 20/D	
Color, Saybolt	
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	
Doctor test	
Flash point, approximate, F	−20 (Est.)

*Literature values.
**Distribution of isomer content varies.

CYCLOOLEFINS

Table 2.96: Cyclopentene *(4)*

FORMULA	$CH_2-CH_2-CH_2$ / $CH=CH$ (ring)		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Pentenes-2	0.02	0.2	3.6
2-Methylbutene-2	0.03	0.2	0.2
Cyclopentene	99.95	99.6	95.7 95.0 min
2-Methylbutene-1			0.1
Pentene-1			0.1
Cyclopentane			0.4
Cyclohexene			
Cyclohexane			

(continued)

Table 2.96: (continued)

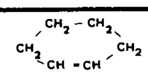
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Unidentified			
Benzene			
Toluene			
Ethylbenzene			
Xylenes			
Purity by freezing point, mol %	99.93	99.5 99.0 min	
Freezing point, F	−211.14*		
Boiling point, F	111.64*		
Distillation range, F			
Initial boiling point			111
Dry point			112
Specific gravity of liquid at 60/60 F	0.7775*	0.778	0.778
at 20/4 C	0.77199*	0.772	0.772
API gravity at 60 F		50.4	50.4
Density of liquid at 60 F, lbs/gal		6.48	6.48
Vapor pressure at 70 F, psia			
100 F, psia			
130 F, psia			
Refractive index, 20/D	1.42246*	1.422	1.422
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Copper corrosion			
Doctor test			
Flash point, approximate, F		−35	
Flammability limits, volume % in air			
Lower			
Higher			

*Literature values.

Cyclopentene and Cyclohexene are sometimes inhibited with 2,6-ditertiarybutyl-4-methylphenol which can be removed by distillation.

Table 2.97: Cyclohexene *(4)*

FORMULA



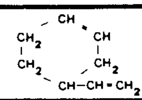
PROPERTIES	RESEARCH GRADE	PURE GRADE
Composition, weight percent		
Pentenes-2		
2-Methylbutene-2		
Cyclopentene		
2-Methylbutene-1		
Pentene-1		
Cyclopentane		
Cyclohexene	99.99	99.5
Cyclohexane	0.01	0.2
Unidentified		0.3
Benzene		
Toluene		
Ethylbenzene		
Xylenes		
Purity by freezing point, mol %	99.92	99.4 99.0 min
Freezing point, F	−154.32*	
Boiling point, F	181.36*	
Distillation range, F		
Initial boiling point		181
Dry point		182
Specific gravity of liquid at 60/60 F	0.8159*	0.816
at 20/4 C	0.81096*	0.811
API gravity at 60 F		41.9
Density of liquid at 60 F, lbs/gal		6.79
Vapor pressure at 70 F, psia		
100 F, psia		3.1
130 F, psia		
Refractive index, 20/D	1.44654*	1.446
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Copper corrosion		
Doctor test		
Flash point, approximate, F		10
Flammability limits, volume % in air		
Lower		
Higher		

*Literature values.

Cyclopentene and Cyclohexene are sometimes inhibited with 2,6-ditertiarybutyl-4-methylphenol which can be removed by distillation.

Table 2.98: 4-Vinylcyclohexene-1 *(4)*

FORMULA:



PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight percent			
2-Methylbutene-1			
2-Methylbutadiene-1,3			
Pentenes-2			
2-Methybutene-2			
trans-Pentadiene-1,3			
cis-Pentadiene-1,3			
Cyclopentene			
Cyclooctadiene-1,5	0.01	0.1	1.5
4-Vinylcyclohexene-1	99.99	99.9	98.5
1-Methylcyclohexene-1			
3-Methylcyclohexene-1			
4-Methylcyclohexane-1			
Unidentified			
Purity by freezing point, mol %	99.88	99.3 99.0 min	97.0 95.0 min
Freezing point, F	−164.07*		
Boiling point, F	262.4*		
Distillation range, F			
Initial boiling point			262
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			265
Specific gravity of liquid at 60/60 F	0.834*	0.836	0.836
at 20/4 C	0.8303*	0.830	0.833
API gravity at 60 F		37.8	37.8
Density of Liquid at 60 F, lbs/gal		6.96	6.96
Vapor pressure at 70 F, psia			
100 F, psia	0.5*	0.5	0.5
130 F, psia			
Refractive index, 20/D		1.464	1.464
Color, Saybolt		+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Doctor test			
Flash point, approximate, F		70	70

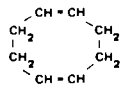
*Literature values.

Table 2.99: Mixed Methylcyclohexenes *(4)*

FORMULA: C_7H_{12}

PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
2-Methylbutene-1	
2-Methylbutadiene-1,3	
Pentenes-2	
2-Methybutene-2	
trans-Pentadiene-1,3	
cis-Pentadiene-1,3	
Cyclopentene	
Cyclooctadiene-1,5	
4-Vinylcyclohexene-1	
1-Methylcyclohexene-1	0.4 }
3-Methylcyclohexene-1	45.5 } 95.0 min
4-Methylcyclohexane-1	52.5 }
Unidentified	1.6
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	215
10% Condensed	
50% Condensed	218
90% Condensed	
Dry point	222
Specific gravity of liquid at 60/60 F	0.8086
at 20/4 C	0.8041
API gravity at 60 F	43.5
Density of Liquid at 60 F, lbs/gal	6.73
Vapor pressure at 70 F, psia	0.6
100 F, psia	2.6
130 F, psia	
Refractive index, 20/D	1.4431
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	
Doctor test	negative
Flash point, approximate, F	30

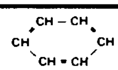
Table 2.100: Cyclooctadiene-1,5 *(4)*

FORMULA		
PROPERTIES	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent		
2-Methylbutene-1		
2-Methylbutadiene-1,3		
Pentenes-2		
2-Methybutene-2		
trans-Pentadiene-1,3		
cis-Pe adiene-1,3		
Cyclopentene		
Cyclooctadiene-1,5	99.8	96.4 95.0 min
4-Vinylcyclohexene-1	0.2	3.6
1-Methylcyclohexene-1		
3-Methylcyclohexene-1		
4-Methylcyclohexane-1		
Unidentified		
Purity by freezing point, mol %	99.5 99.0 min	
Freezing point, F	−69.53*	
Boiling point, F		
Distillation range, F		
Initial boiling point		298
10% Condensed		
50% Condensed		
90% Condensed		
Dry point		304
Specific gravity of liquid at 60/60 F	0.8865*	0.886
at 20/4 C	0.8833*	0.883
API gravity at 60 F		28.2
Density of Liquid at 60 F, lbs/gal		7.38
Vapor pressure at 70 F, psia		
100 F, psia	0.5*	0.5
130 F, psia		
Refractive index, 20/D	1.4933*	1.493
Color, Saybolt	+30	+30
Acidity, distillation residue		
Nonvolatile matter, grams/100 ml		
Doctor test		
Flash point, approximate, F	100	96

*Literature values.

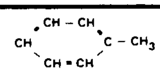
AROMATICS

Table 2.101: Benzene *(4)*

FORMULA		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
Pentenes-2		
2-Methylbutene-2		
Cyclopentene		
2-Methylbutene-1		
Pentene-1		
Cyclopentane		
Cyclohexene		
Cyclohexane		
Unidentified		
Benzene	99.99	99.8
Toluene	0.01	0.1
Ethylbenzene		0.1
Xylenes		
Purity by freezing point, mol %	99.90	99.7 99.0 min
Freezing point, F	41.96*	
Boiling point, F	176.18*	
Distillation range, F		
Initial boiling point		175
Dry point		177
Specific gravity of liquid at 60/60 F	0.8845*	0.884
at 20/4 C	0.87901*	0.879
API gravity at 60 F		28.6
Density of liquid at 60 F, lbs/gal		7.36
Vapor pressure at 70 F, psia	1.53*	1.5
100 F, psia	3.22*	3.2
130 F, psia	6.20*	6.2
Refractive index, 20/D	1.50112*	1.501
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Copper corrosion		
Doctor test		negative
Flash point, approximate, F		10
Flammability limits, volume % in air		
Lower	1.3*	
Higher	7.9*	

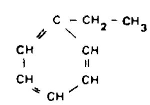
*Literature values.

Table 2.102: Toluene *(4)*

FORMULA		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
Pentenes-2		
2-Methylbutene-2		
Cyclopentene		
2-Methylbutene-1		
Pentene-1		
Cyclopentane		
Cyclohexene		
Cyclohexane		
Unidentified		
Benzene	0.01	0.1
Toluene	99.99	99.8
Ethylbenzene		
Xylenes		0.1
Purity by freezing point, mol %	99.90	99.7 99.0 min
Freezing point, F	−138.98*	
Boiling point, F	231.12*	
Distillation range, F		
Initial boiling point		230
Dry point		231
Specific gravity of liquid at 60/60 F	0.8719*	0.872
at 20/4 C	0.86696*	0.867
API gravity at 60 F		30.8
Density of liquid at 60 F, lbs/gal		7.26
Vapor pressure at 70 F, psia	0.45*	0.4
100 F, psia	1.03*	1.0
130 F, psia	2.15*	2.2
Refractive index, 20/D	1.49693*	1.497
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Copper corrosion		1
Doctor test		
Flash point, approximate, F		40 (D 56)
Flammability limits, volume % in air		
Lower	1.2* 212F	
Higher	7.1* 212F	

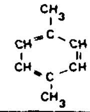
*Literature values.

Table 2.103: Ethylbenzene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Benzene	0.01	0.3	0.6
Toluene	0.01	0.2	0.4
Ethylbenzene	99.98	99.5	99.0
para-Xylene			
meta-Xylene			
ortho-Xylene			
Purity by freezing point, mol %	99.92	99.2 99.0 min	98.5 95.0 min
Freezing point, F	−138.96*		
Boiling point, F	277.13*		
Distillation range, F			
Initial boiling point			277
Dry point			278
Specific gravity of liquid at 60/60 F	0.8717*	0.872	0.872
at 20/4 C	0.86702*	0.867	0.867
API gravity at 60 F		30.8	30.8
Density of liquid at 60 F, lbs/gal		7.26	7.26
Vapor pressure at 100 F, psia	0.37*	0.4	0.4
130 F, psia	0.84*	0.8	0.8
Refractive index, 20/D	1.49588*	1.496	1.496
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Acid wash color			
Color			
Doctor test			
Flash point, approximate, F		59 (D1310)	59 (D 1310)
Flammability limits, volume % in air			
Lower	1.0*		
Higher	6.7*		

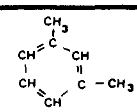
*Literature values.
Ethylbenzene is sometimes stablized with 2,6-ditertiarybutyl-4-methylphenol which can be removed by distillation.

Table 2.104: p-Xylene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Benzene			
Toluene			
Ethylbenzene			
para-Xylene	99.99	99.8	99.0
meta-Xylene	0.01	0.2	0.6
ortho-Xylene		trace	0.4
Purity by freezing point, mol %	99.94	99.5 99.0 min	98.0 95.0 min
Freezing point, F	55.87*		
Boiling point, F	281.03*		
Distillation range, F			
Initial boiling point			280
Dry point			281
Specific gravity of liquid at 60/60 F	0.8657*	0.866	0.866
at 20/4 C	0.86105*	0.861	0.861
API gravity at 60 F		31.9	31.9
Density of liquid at 60 F, lbs/gal		7.21	7.21
Vapor pressure at 100 F, psia	0.34*	0.3	0.3
130 F, psia	0.77*	0.8	0.8
Refractive index, 20/D	1.49582*	1.496	1.496
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Acid wash color		1	1
Color		Pass	Pass
Doctor test			
Flash point, approximate, F		81	81
Flammability limits, volume % in air			
Lower	1.1*		
Higher	6.6*		

*Literature values.

Table 2.105: m-Xylene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Benzene			
Toluene			
Ethylbenzene			0.1
para-Xylene	0.01	0.1	0.4
meta-Xylene	99.99	99.9	99.2
ortho-Xylene			0.3
Purity by freezing point, mol %	99.94	99.2 99.0 min	98.2 95.0 min
Freezing point, F	−54.17*		
Boiling point, F	282.39*		
Distillation range, F			
Initial boiling point			280
Dry point			281
Specific gravity of liquid at 60/60 F	0.8687*	0.869	0.869
at 20/4 C	0.86417*	0.864	0.864
API gravity at 60 F		31.3	31.3

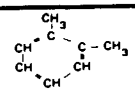
(continued)

Table 2.105: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Density of liquid at 60 F, lbs/gal		7.24	7.24
Vapor pressure at 100 F, psia	0.33*	0.3	0.3
130 F, psia	0.74*	0.7	0.7
Refractive index, 20/D	1.49722*	1.497	1.497
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Acid wash color			
Color			
Doctor test		negative	negative
Flash point, approximate, F		84	84
Flammability limits, volume % in air			
Lower	1.1*		
Higher	6.4*		

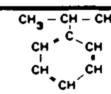
*Literature values.

Table 2.106: o-Xylene *(4)*

FORMULA		
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**
Composition, weight percent		
meta-Xylene	0.01	0.3
ortho-Xylene	99.99	99.7
Ethylbenzene		
Isopropylbenzene		
Normal Propylbenzene		
Methylethylbenzenes		
1,2,4-Trimethylbenzene		
1,3,5-Trimethylbenzene		
1,2,3-Trimethylbenzene		
Purity by freezing point, mol %	99.96	99.4 99.0 min
Freezing point, F	−13.33*	
Boiling point, F	291.94*	
Distillation range, F		
Initial boiling point		289
Dry point		291
Specific gravity of liquid at 60/60 F	0.8848*	0.885
at 20/4 C	0.88020*	0.880
API gravity at 60 F		28.4
Density of liquid at 60 F, lbs/gal		7.37
Vapor pressure at 100 F, psia	0.26*	0.3
130 F, psia	0.61*	0.6
Refractive index, 20/D	1.50545*	1.505
Color, Saybolt	+30	+30
Acidity, distillation residue		neutral
Nonvolatile matter, grams/100 ml		0.0005
Flash point, approximate, F		88 (D 56)
Flammability limits, volume % in air		
Lower	1.1*	
Higher	6.4*	

*Literature values.

Table 2.107: Cumene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
meta-Xylene			
ortho-Xylene	0.01	0.1	0.2
Ethylbenzene	0.03	0.3	0.6
Isopropylbenzene	99.96	99.6	99.2
Normal Propylbenzene			
Methylethylbenzenes			
1,2,4-Trimethylbenzene			
1,3,5-Trimethylbenzene			
1,2,3-Trimethylbenzene			
Purity by freezing point, mol %	99.92	99.3 99.0 min	98.5 95.0 min
Freezing point, F	−140.86*		
Boiling point, F	306.31*		
Distillation range, F			
Initial boiling point		306	
Dry point		307	
Specific gravity of liquid at 60/60 F	0.8663*	0.866	0.866
at 20/4 C	0.86179*	0.862	0.862
API gravity at 60 F		31.9	31.9
Density of liquid at 60 F, lbs/gal		7.21	7.21
Vapor pressure at 100 F, psia	0.19*	0.2	0.2
130 F, psia	0.45*	0.4	0.4
Refractive index, 20/D	1.49145*	1.491	1.491
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		111	111
Flammability limits, volume % in air			
Lower	0.9*		
Higher	6.5*		

*Literature values.

Isopropylbenzene and 1,2,4-Trimethylbenzene are sometimes stabilized with 2,6-ditertiary butyl-4-methylphenol which can be removed by distillation.

Table 2.108: n-Propylbenzene *(4)*

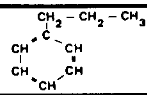
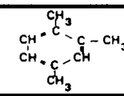
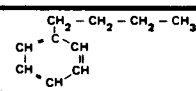
FORMULA	
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
meta-Xylene	
ortho-Xylene	
Ethylbenzene	
Isopropylbenzene	1.5
Normal Propylbenzene	96.6 95.0 min
Methylethylbenzenes	1.9
1,2,4-Trimethylbenzene	
1,3,5-Trimethylbenzene	
1,2,3-Trimethylbenzene	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	315
Dry point	319
Specific gravity of liquid at 60/60 F	0.8669
at 20/4 C	0.8621
API gravity at 60 F	31.7
Density of liquid at 60 F, lbs/gal	7.22
Vapor pressure at 100 F, psia	
130 F, psia	
Refractive index, 20/D	1.4915
Color, Saybolt	+30
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	0.0005
Flash point, approximate, F	114
Flammability limits, volume % in air	
Lower	
Higher	

Table 2.109: Pseudocumene *(4)*

FORMULA			
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight percent			
meta-Xylene			
ortho-Xylene			
Ethylbenzene			
Isopropylbenzene			
Normal Propylbenzene			
Methylethylbenzenes		0.2	1.6
1,2,4-Trimethylbenzene	99.99	99.7	96.1
1,3,5-Trimethylbenzene	0.01	0.1	1.4
1,2,3-Trimethylbenzene			0.9
Purity by freezing point, mol %	99.90	99.5 99.0 min	95.5 95.0 min
Freezing point, F	−46.84*		
Boiling point, F	336.83*		
Distillation range, F			
Initial boiling point		336	
Dry point		337	
Specific gravity of liquid at 60/60 F	0.8802*	0.880	0.880
at 20/4 C	0.87582*	0.876	0.876
API gravity at 60 F		29.3	29.3
Density of liquid at 60 F, lbs/gal		7.33	7.33
Vapor pressure at 100 F, psia			
130 F, psia	0.22*	0.2	0.2
Refractive index, 20/D	1.50484*	1.505	1.505
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Flash point, approximate, F		130	130
Flammability limits, volume % in air			
Lower			
Higher			

*Literature values.
Isopropylbenzene and 1,2,4-Trimethylbenzene are sometimes stabilized with 2,6-ditertiary butyl-4-methylphenol which can be removed by distillation.

Table 2.110: n-Butylbenzene *(4)*

FORMULA			
PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Composition, weight percent			
secondary-Butylbenzene		0.2	3.8
normal-Butylbenzene	99.8	99.4	95.6 95.0 min
1-Phenylbutene-2			0.6
other Alkylbenzenes	0.2	0.4	
other Phenylbutenes			
secondary-Amylbenzene			
3-Phenylpentane			
2-Phenyl-2-methylbutane			
Light Amylbenzenes			
Alkylbenzenes			
secondary-Butyl Chloride			
Butenes			
Purity by freezing point, mol %	99.50	99.2 99.0 min	
Freezing point, F	−126.35*		
Boiling point, F	361.89*		
Distillation range, F			
Initial boiling point			
10% Condensed			
50% Condensed			
90% Condensed			
Dry point			

(continued)

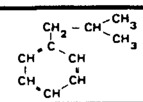
Table 2.110: (continued)

PROPERTIES	RESEARCH GRADE	PURE GRADE	TECHNICAL GRADE
Specific gravity of liquid at 60/60 F	0.8646*	0.865	0.865
at 20/4 C	0.86013*	0.860	0.860
API gravity at 60 F		32.1	32.1
Density of liquid at 60 F, lbs/gal		7.20	7.20
Refractive index, 20/D	1.48979*	1.490	1.490
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Color Alpha			
Flash point, approximate, F		160	160
Flammability limits, volume % in air			
Lower	0.8		
Higher	5.8		

*Literature values.

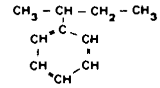
Normal Butylbenzene is sometimes stablized with tertiary-butylcatechol (TBC) which can be removed by distillation.

Table 2.111: Isobutylbenzene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Toluene	0.01	0.2	0.5
Isopropylbenzene			
tertiary-Butylbenzene			
Isobutylbenzene	99.97	99.6	99.1
secondary-Butylbenzene			
normal-Butylbenzene	0.02	0.2	0.4
Water, ppm, weight		<100	<100
Purity by freezing point, mol %	99.80	99.3 99.0 min	98.5 95.0 min
Freezing point, F	−60.66*		
Boiling point, F	342.97*		
Distillation range, F			
Initial boiling point		340	337
Dry point		343	344
Specific gravity of liquid at 60/60 F	0.8576*	0.858	0.858
at 20/4 C	0.85321*	0.853	0.853
API gravity at 60 F		33.4	33.4
Density of liquid at 60 F, lbs/gal		7.14	7.14
Vapor pressure at 130 F, psia	0.21	0.2	0.2
Refractive index, 20/D	1.48646*	1.486	1.486
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml			
Aniline point, F			
Bromine number			
Flash point, approximate, F		140	140

*Literature values.

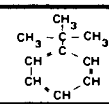
Table 2.112: sec-Butylbenzene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Toluene			
Isopropylbenzene			
tertiary-Butylbenzene	0.02	0.6	0.9
Isobutylbenzene			0.1
secondary-Butylbenzene	99.98	99.4	98.9
normal-Butylbenzene			0.1
Water, ppm, weight			
Purity by freezing point, mol %	99.93	99.2 99.0 min	96.7 95.0 min
Freezing point, F	−103.85*		
Boiling point, F	343.95*		
Distillation range, F			
Initial boiling point			338
Dry point			343
Specific gravity of liquid at 60/60 F	0.8664*	0.866	0.866
at 20/4 C	0.86207*	0.862	0.862
API gravity at 60 F		31.9	31.9
Density of liquid at 60 F, lbs/gal		7.21	7.21
Vapor pressure at 130 F, psia	0.20	0.2	0.2
Refractive index, 20/D	1.49020*	1.490	1.490
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Aniline point, F		−20	
Bromine number		0.5	
Flash point, approximate, F		126	126

*Literature values.

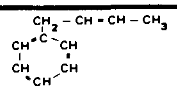
Secondary-Butylbenzene is sometimes stablized with tertiary-butylcatechol (TBC) which can be removed by distillation.

Table 2.113: tert-Butylbenzene *(4)*

FORMULA			
PROPERTIES	**RESEARCH GRADE**	**PURE GRADE**	**TECHNICAL GRADE**
Composition, weight percent			
Toluene			
Isopropylbenzene		0.1	0.5
tertiary-Butylbenzene	99.99	99.8	98.2
Isobutylbenzene			
secondary-Butylbenzene	0.01	0.1	1.1
normal-Butylbenzene			0.2
Water, ppm, weight			
Purity by freezing point, mol %	99.82	99.4 99.0 min	97.0 95.0 min
Freezing point, F	−72.13*		
Boiling point, F	336.41*		
Distillation range, F			
Initial boiling point		336	331
Dry point		337	336
Specific gravity of liquid at 60/60 F	0.8710*	0.871	0.871
at 20/4 C	0.86650*	0.866	0.866
API gravity at 60 F		31.0	31.0
Density of liquid at 60 F, lbs/gal		7.25	7.25
Vapor pressure at 130 F, psia	0.23	0.2	0.2
Refractive index, 20/D	1.49266*	1.493	1.493
Color, Saybolt	+30	+30	+30
Acidity, distillation residue		neutral	neutral
Nonvolatile matter, grams/100 ml		0.0005	0.0005
Aniline point, F			
Bromine number			
Flash point, approximate, F		140	140

*Literature values.

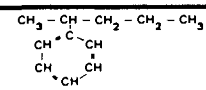
Table 2.114: 1-Phenylbutene-2 *(4)*

FORMULA	
PROPERTIES	TECHNICAL GRADE
Composition, weight percent	
secondary-Butylbenzene	
normal-Butylbenzene	
1-Phenylbutene-2	96.4 95.0 min
other Alkylbenzenes	
other Phenylbutenes	3.6
secondary-Amylbenzene	
3-Phenylpentane	
2-Phenyl-2-methylbutane	
Light Amylbenzenes	
Alkylbenzenes	
secondary-Butyl Chloride	
Butenes	
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	360
10% Condensed	
50% Condensed	
90% Condensed	
Dry point	367
Specific gravity of liquid at 60/60 F	0.888
at 20/4 C	
API gravity at 60 F	27.8
Density of liquid at 60 F, lbs/gal	7.40
Refractive index, 20/D	1.511
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	0.0005
Color Alpha	
Flash point, approximate, F	160
Flammability limits, volume % in air	
Lower	
Higher	

*Literature values.

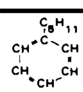
1-Phenylbutene-2 is sometimes stabilized with tertiary-butylcatechol (TBC) which can be removed by distillation.

Table 2.115: sec-Amylbenzene *(4)*

FORMULA		
PROPERTIES	PURE GRADE	TECHNICAL GRADE
Composition, weight percent		
secondary-Butylbenzene		
normal-Butylbenzene		
1-Phenylbutene-2		
other Alkylbenzenes		
other Phenylbutenes		
secondary-Amylbenzene	99.5 99.0 min	97.3 95.0 min
3-Phenylpentane	0.1	0.8
2-Phenyl-2-methylbutane	0.4	1.9
Light Amylbenzenes		
Alkylbenzenes		
secondary-Butyl Chloride		
Butenes		
Purity by freezing point, mol %		
Freezing point, F		
Boiling point, F	379.4*	
Distillation range, F		
Initial boiling point	374	370
10% Condensed		
50% Condensed		
90% Condensed		
Dry point	380	380
Specific gravity of liquid at 60/60 F	0.8628*	0.863
at 20/4 C	0.8585	0.858
API gravity at 60 F		32.5
Density of liquid at 60 F, lbs/gal		7.18
Refractive index, 20/D	1.4876*	1.488
Color, Saybolt	+30	+30
Acidity, distillation residue	neutral	neutral
Nonvolatile matter, grams/100 ml		
Color Alpha		
Flash point, approximate, F	155	155
Flammability limits, volume % in air		
Lower		
Higher		

*Literature values.

Table 2.116: Mixed Amylbenzenes *(4)*

FORMULA	
PROPERTIES	PURE GRADE
Composition, weight percent	
secondary-Butylbenzene	
normal-Butylbenzene	
1-Phenylbutene-2	
other Alkylbenzenes	
other Phenylbutenes	
secondary-Amylbenzene	38.8 } 99.0 min
3-Phenylpentane	39.2 } 99.0 min
2-Phenyl-2-methylbutane	21.7 } 99.0 min
Light Amylbenzenes	0.2
Alkylbenzenes	0.1
secondary-Butyl Chloride	
Butenes	
Distillation range, F	
Initial boiling point	369.6
10% Condensed	370.4
50% Condensed	371.6
90% Condensed	372.0
Dry point	372.4
Specific gravity of liquid at 60/60 F	
at 20/4 C	0.864
API gravity at 60 F	
Density of liquid at 60 F, lbs/gal	7.25
Refractive index, 20/D	1.490
Color, Saybolt	+30
Acidity, distillation residue	neutral
Nonvolatile matter, grams/100 ml	
Color Alpha	
Flash point, approximate, F	155
Flammability limits, volume % in air	
Lower	
Higher	

*Literature values.

Table 2.117: DIPENTENE No. 122 Terpene Solvent *(28)*

DIPENTENE NO. 122® a terpene solvent with a pleasant terpene odor obtained by fractionation of oils extracted from pinewood, meets the Federal specification for commercial dipentene. It can be used as a component in solvent systems for oleoresin-based coatings, and as an antiskinning agent. Other uses include the production of dipping finishes and various chemical specialties.

General Sales Specifications
Hercules Test Methods are available on request

Color, Hazen (APHA)[a], max	0.5
Specific gravity at 15.6/15.6°C	0.845-0.865
Refractive index at 20°C	1.472-1.477
ASTM Distillation, °C 1st cc - 95%	168 min - 188 max

(a)American Public Health Association

Typical Properties

Specific gravity at 15.6/15.6°C	0.853
Refractive index at 20°C	1.475
Distillation range, °C, 5%	175
95%	183
Freezing point, °C	<-40
Flashpoint, TCC, °C (°F)	49 (120)
Aniline point, °C	<0
Unpolymerized residue, %	1.5
Monocyclic terpenes, %	91
Dipentene, %	37
Kauri-butanol value	62

Outstanding Characteristics
High clarity; near colorlessness; pleasant odor; high solvency; good antiskinning properties; good wetting and dispersing properties for pigments.
Solvent for synthetic and natural resins, rubber, waxes, raw and polymerized oils, and metallic driers.

Table 2.118: SOLVENOL 2 Terpene Solvent *(28)*

A High-Solvency Terpene Hydrocarbon

SOLVENOL® 2 terpene solvent is a pale yellow to near colorless liquid that has high solvency for resins, waxes, and greases. It is exceptionally effective as a softening and swelling agent for rubber. Of pine-wood origin, it is a mixture of monocyclic terpenes with a stronger solvency than turpentine for waxes and resins.

General Sales Specifications
Hercules Test Methods are available on request

Specific gravity at 15.6/15.6°C	0.845-0.870
Distillation range, °C, first cm³, min	165
95%, max	195

Typical Properties

Specific gravity at 15.6/15.6°C	0.860
Distillation range, °C, 5%	166
95%	183
Color, Hazen	45
Hercules terpene	0.3
Freezing point, °C	<-40
Flashpoint, TCC, °F (°C)	115 (46)
Kauri-butanol value	80
Aniline point, °F (°C)	<23 (<-5)
Density at 60°F (15.6°C), lbs/gal (kg/l)	7.17 (.86)

Outstanding Characteristics
Clear, near colorless liquid; high solvent power; highly effective softening and swelling agent for natural and synthetic rubbers.

Table 2.119: SOLVENOL 226 Terpene Solvent *(28)*

SOLVENOL® 226 terpene solvent is a pale yellow to near colorless liquid that has high solvency for resins, waxes, and greases. Of pinewood origin, it is a mixture of monocyclic terpenes rich in *para* -menthane. It is used as a solvent in the manufacture of cleaning compounds; textile dyes; waxes and polishes for floor, furniture, leather, and shoes; and in other chemical specialties.

General Sales Specifications	
Hercules Test Methods are available on request	
Specific gravity at 15.6/15.6°C	0.829-0.840
Distillations range, °C	
5%, min	158
95%, max	180
Typical Properties	
Specific gravity at 15.6/15.6°C	0.838
Refractive index at 20°C	1.460
Distillation range, °C	
5%, min	165
95%, max	172
Color, Hazen	45
Freezing point, °F(°C)	-40
Flashpoint (SETA), °F(°C)	108 (42)
Kauri-butanol (KB) value	62
Aniline point, °F (°C)	73 (23)
Density at 60°F (15.6°C), lbs/gal (kg/l)	7 (0.84)
Unpolymerized residue, %	30

Outstanding Characteristics

Clear, near colorless liquid; high solvent power; excellent wetting and penetrating properties.

Table 2.120: HERCULES Steam-Distilled Wood Turpentine *(28)*

HERCULES® SDW TURPENTINE is a clear, water-white liquid that complies with all requirements of Federal and ASTM specifications for pure spirits of turpentine.

General Sales Specifications	
Hercules Test Methods are available on request	
Specific gravity at 15.6/15.6°C	0.860-0.866
Refractive index at 20°C	1.465-1.469
ASTM distillation range, °C, 5%	154.0
95%	170.0
Typical Properties	
Specific gravity at 15.6/15.6°C	0.861
Refractive index at 20°C	1.468
Unpolymerized residue, %	1.3
Initial boiling point, °C	150
ASTM distillation below 170°C, %	98
Freezing point, °C	<-40
Aniline point, °C	21
Kauri-butanol value	56
Moisture	trace
Flashpoint, TCC, °C(°F)	36 (97)
Color (Hercules terpene)	0.1
Density at 60°F (15.6°C), lbs/gal (kg/l)	7.18 (.86)

Outstanding Characteristics

Clarity; water-white color; typical turpentine odor; high solvency power; excellent wetting and penetrating properties; uniform purity.

Solvent for raw and bodied drying oils, and for natural and synthetic resins and waxes.

Table 2.121: HERCULES alpha-Pinene *(28)*

HERCULES® alpha-pinene is a clear, water-white product obtained by fractional distillation of steam-distilled wood turpentine. It consists predominantly of the bicyclic terpene hydrocarbon, alpha-pinene. Hercules alpha-pinene can be used wherever a high-purity-grade alpha-pinene is required.

General Sales Specifications

Hercules Test Methods are available on request

Specific gravity at 15.6°C/15.6°C	0.8620-0.8645
Refractive index at 20°C	1.4655-1.4670
Distillationrange,°C,5%min-95%max	155-159

Typical Properties

Specific gravity at 15.6°C/15.6°C	0.863
Refractive index at 20°C	1.466
Components, %	
alpha-pinene	84.7
Camphene	13.9
beta-pinene	0.5
Distillation range, °C, 5%-95%	156-158
Color, Hercules terpene	0.1
Freezing point, °C	<-40
Flashpoint, Tag closed up, °F (°C)	91 (33)
Kauri-butanol value	52
Density at 60°F (15.6°C), lbs,/gal (kg/l)	7.2 (0.86)

Outstanding Characteristics

Clear, water-white, high purity, chemically reactive, excellent solvent, narrow distallation range.

Table 2.122: Selected Properties of Some Common Terpene Solvents *(43)*

SOLVENT	KAURI BUTANOL	BOIL. RANGE, °C INITIAL	DRY PT.	SPEED OF EVAPOR., MINUTES	FLASH PT. TCC°F	Solubility Pararameter $(Cal/cc)^{1/2}$
Dipentenes	62	175	188	33.0	125[a]	
Gum Turpentine	65	155	183	16.0	93[a]	8.2
Limonene 125	58	162	179		112	
Pine Oil	>500	204	227	500.0	188[a]	8.61
Terpene SW	>500	209	234	500.0	180	

a "Organic Solvents," Central Solvents & Chemical Co.

Table 2.123: Arizona Terpene Products *(5)*

ACINTENE® A ALPHA-PINENE

ACINTENE® A is a clear, colorless liquid with a mild turpentine-like odor which is very high in alpha-pinene content. ACINTENE® A is miscible in alcohols and insoluble in water.

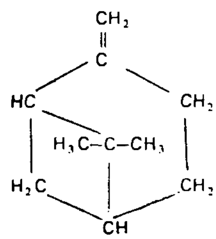
PRODUCT PROPERTIES

	Specifications	Typical Analysis
Color, APHA[1]	20 max.	5
Distillation Range, °C[2]		
First Drop		156.3
97%		157.4
Moisture, %[3]	<0.1	<0.1
Kauri-butanol Value[4]		68
Composition:[5]		
Alpha-pinene, %	91 min.	93.0
Camphene, %		2.5
Beta-pinene, %		2.5
Other Terpenes, %		2.0
Specific Gravity, 15.5°/15.5°C[2]		0.8636
Weight Per Gallon, 15°C, lb		7.19
Refractive Index, 20°C[2]		1.4661
Flash Point, Closed Cup, °C(°F)[6]		33(91)

Methods of Analysis:

1. ASTM D 1209-79
2. ASTM D 802-82
3. Arizona Method
4. ASTM D 1133-86
5. By Gas Chromatography. Arizona Chemical Company method furnished upon request
6. ASTM D 93-85 by tag-closed tester

ACINTENE® B Beta Pinene



ACINTENE B Beta Pinene is obtained by fractional distillation of sulfate turpentine. It is used as an intermediate in the manufacture of synthetic resins.

Product Characteristics	Specification	Typical Analysis	Method of Analysis
Color, APHA	20 max.	5	ASTM D1209-62
Distillation Range, °C:			ASTM D233-65
First Drop	165-167	166	
90%	167-169	169	
97%	169-173	172	
Specific Gravity, 15.5°C/15.5°C	0.8685 min. 0.8715 max.	0.8708	ASTM D233-65
25°C/25°C		0.8654	
Refractive Index, 20°C	1.4760 min. 1.4780 max.	1.4774	ASTM D233-65
Flash Point, Closed Cup, °F		100	ASTM D56-64
Moisture, %	0.0	0.0	Arizona Method
Composition by GLC:			
α-Pinene, %		7.5	
β-Pinene, %		76.3	
Dipentene, %		11.0	
Camphene, %		1.7	
p-Cymene, %		0.5	
Others, %		3.0	
Pounds Per Gallon, 15°C		7.25	
25°C		7.19	

(continued)

Table 2.123: (continued)

ACINTENE® DP DIPENTENE

ACINTENE® DP is a clear, yellowish liquid with a lemon-pine-like odor. It is obtained by several fractional distillations of crude sulfate turpentine. ACINTENE DP is not a co-product of any process and is sometimes referred to as a "natural" dipentene. ACINTENE DP is miscible in alcohols and insoluble in water.

PRODUCT PROPERTIES

	Specifications	Typical Analysis
Color, Gardner [1]	2 max.	<1
Distillation Range, °C [2]		
First Drop		177
95%		187
Kauri-Butanol Value [3]		90
Composition: [4]		
Alpha-Pinene, %		<1
Beta-Pinene, %		5
Camphene, %		<1
Myrcene/Carene, %		1
Dipentene, % *		73
Para-Cymene/Terpinolene, %		10
Terpene Alcohols, %		<1
Other Terpenes, %		10
Specific Gravity, 15.5°/15.5°C [2]		0.8558
Weight Per Gallon, 15°C, lb		7.13
Refractive Index, 20°C [2]		1.4779
Flash Point, Closed Cup, °C(°F) [5]		54 (130)

* Includes some beta-phellandrene.

Methods of Analysis:

1. ASTM D 1544-86; Using Gardner color disks - 1963 standard, 50% in heptane.
2. ASTM D 802-82
3. ASTM D 1133-86
4. By Gas-Liquid Chromatography. Arizona Chemical Company method furnished on request.
5. ASTM D 93-85 by tag-closed tester

ACINTENE® CRDB TERPENE

PRODUCT PROPERTIES

	Specification	Typical Analysis
Color, Gardner[1]		15
AN		<0.5
Moisture, %[2]		0
Composition:[3]		
Total Terpene Alcohols, %		36
Alpha-Terpineol, %		21
Cis-Anethole, %		4
Trans-Anethole, %	15 min.	19
Methyl Chavicol, %	10 min.	15
Other Terpene Alcohols, %		15
Other, %		26
Specific Gravity, 15.5°/15.5°C[2]		0.959
Weight Per Gallon, 15°C, lb		7.8
EPA 24 Volitals		99.8
Flash Point, Closed Cup, °C(°F)[4]		91(195)

METHODS OF ANALYSIS:

1. ASTM D 1544-86
2. ASTM D 803-93
3. By Gas-Liquid Chromatography. Arizona Chemical Company method furnished on request.
4. ASTM D 93-85 by Tag-Closed Tester

(continued)

Table 2.123: (continued)

ACINTENE® N LIQUID TERPENE POLYMER

ACINTENE® N is a dark brown, very viscous liquid obtained from the fractional distillation of sulfate turpentine It is composed of terpene dimers and polymers. ACINTENE N is soluble in turpentine, aromatic solvents, and mineral spirits.

PRODUCT PROPERTIES

	Specifications	Typical Analysis
Color, Gardner [1]	18 max.	17
Moisture, % [2]	0.2 max.	0.05
Specific Gravity, 15.5°/15.5°C [2]		0.963
Weight Per Gallon, 15°C, lb		8.02
Viscosity, Gardner-Holdt, 25°C [2]	Z_8 min.	Z_8+
Viscosity, cps, 25°C		3400
Flash Point, Closed Cup, °C(°F) [3]	150 (300) min.	163 (325)

Methods of Analysis:
1. ASTM D 1544-86; Using Gardner color disks - 1963 standard, 50% in heptane
2. ASTM D 802-82
3. ASTM D 93-85 by tag-closed tester

ACINTENE® L TURPENTINE BOTTOMS FRACTION

ACINTENE® L is a dark brown, viscous liquid obtained from the fractional distillation of sulfate turpentine. It is composed of diterpenes, triterpenes, and higher molecular-weight terpene polymers. ACINTENE L is soluble in turpentine, aromatic solvents, and mineral spirits.

PRODUCT PROPERTIES

	Typical Analysis
Color, Gardner [1]	13+
Specific Gravity, 15.5°/15.5°C [2]	0.96
Weight Per Gallon, 15°C, lb	8.00
Viscosity, Gardner-Holdt, 25°C [2]	Z_2
Viscosity, cps, 25°C	3400
Flash Point, Closed Cup, °C(°F) [3]	163 (325)

Methods of Analysis
1. ASTM D 1544-86; Using Gardner color disks - 1963 standard, 50% in heptane
2. ASTM D 802-82
3. ASTM D 93-85 by tag-closed tester

COMPARATIVE DATA

Table 2.124: Amoco PANASOL Solvents *(20)*

Panasol solvents sales specifications*

	Panasol AB-130	Panasol AN-2K	Panasol AN-3N	Panasol AN-3S
Specific gravity				
at 16°C(61°F), ASTM D4052	0.860 - 0.890	0.934 - 0.947	0.979 - 1.007	0.979 - 1.007
at 25°C/25°C, ASTM D4052	—	—	—	—
Distillation point, ASTM D86				
Initial boiling point, °C (°F), min.	149(300)	177 (350)	210 (410)	232 (450)
95% boiling point, °C (°F)	202(395)	—	—	—
End point, °C (°F), max.	—	288 (550)	288 (550)	288 (550)
Flash point, ASTM D56, TCC,				
°C (°F), min.	38(100)	63(145)	—	—
°C (°F), max.	57(135)	—	—	—
Flash point, ASTM D93, PMCC				
°C (°F), min.	—	—	95(203)	95(203)
Color, ASTM D1500, max.	1.0	2.0	2.0	2.0
Appearance at 16°C(61°F), visual test	clear, no free suspended matter	clear, no free suspended matter	clear, no free suspended matter	clear, no free suspended matter
Aromatics, ASTM D1319, vol %, min.	98	78	95	95
Copper corrosion, ASTM D849	—	Pass	Pass	Pass

Panasol Solvents non-specification properties

Inspection Tests	AN-2K	AN-3N	AN-3S	HAB-500	AB-130
API Gravity @ 60°F	20.3	11.8	10.9	13.2	30.4
Specific Gravity @ 60°F	0.932	0.987	0.994	0.978	0.874
Lbs./Gal. @ 60°F	7.762	8.224	8.276	8.110	7.278
ASTM Color	0.5	0.5	<1.0	3.5	<0.5
TCC Flash Point,°F	151	208	>212	207	127
Mixed Aniline Point,°F	76.5	53.8	52.7	57.4	60.4
Kauri-Butanol Value	—	98.0	89.0	65.0	85.0
Aromatics, Weight %	86.0	99.5	99.2	99.8	98.6
Mono-aromatics	31.6	13.9	5.1	8.5	96.6
Di-aromatics	54.4	85.6	94.1	91.3	2.0
Molecular Weight by VPO	175	164	157	196	215
Crystallization Point,°F	-48	-8	+5	-45	-48
Pour Point,°F	-54	-17	-11	<-76	-71
Distillation,°F					
Initial Boiling Point	354	436	470	412	328
5	376	450	482	466	340
10	386	456	488	516	344
20	404	464	492	532	347
30	418	470	496	546	350
40	430	474	498	556	351
50	444	478	501	565	352
60	456	484	504	572	354
70	468	490	506	578	356
80	480	498	510	584	360
90	494	510	518	594	364
95	508	522	526	610	369
End Point	532	540	543	649	422
XRF Sulfur Content, ppm	*ND	*ND	*ND	*ND	*ND
XRF Chloride Content, ppm	68	*ND	9	*ND	*ND

*ND= None detected

Table 2.125: Ashland Aliphatic and Aromatic Solvents *(69)*

Aliphatic Solvents

PRODUCT	LB./GAL. 60° F	SP. GR. 60°/60° F	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F TCC	KB	ANILINE PT. °F	% ARO.	EVAP RATE[1]
Pentane	5.26	0.631	34-40	94-104	<0	26	—	0	8.1
Hexane	5.61	0.675	65-70	149-158	<0	29	151	<0.1	6.3
Cyclohexane	6.53	0.784	80-82	176-180	0	55	65[2]	0	5.5
LACOLENE™	6.04	0.725	91-109	195-229	18	33	150	<1	2.4
Super LACOLENE™	6.31	0.758	91-110	195-230	18	47	105	20	2.2
Heptane	5.79	0.695	92-100	198-212	15	30	146	0.1	4.5
VM & P Naphtha	6.20	0.744	119-141	246-285	50	32	153	<1	1.6
90 Solvent	6.35	0.762	140-163	285-325	86	34	150	<1	0.33
KWIK DRI™	6.44	0.772	154-182	310-360	105	32	154	<1	0.20
Rule 66 Mineral Spirits	6.44	0.773	154-196	310-385	105	32	155	<1	0.12
Mineral Spirits, NE	6.50	0.780	154-205	310-400	105	36	139	14	0.12
Odorless Mineral Spirits	6.32	0.759	174-213	345-415	125	28	185	<1	0.11
Low Odor Base Solvent	6.61	0.793	182-201	370-550	150	30	166	4	<0.01
140 Solvent	6.54	0.785	188-288	360-394	142	31	160	1	0.08
Mineral Seal Oil	6.79	0.816	254-318	490-605	265[3]	22	187	8	<0.01

[1] n-Butyl Acetate = 1 [2] Mixed Aniline Point [3] COC

Aromatic Solvents

PRODUCT	LB./GAL. 60° F	SP. GR. 60°/60° F	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F TCC	KB	MAP	EVAP. RATE[1]
Toluene	7.27	0.873	110-111	230-233	45	105	50	1.8
Ethyl Benzene	7.26	0.871	135-137	275-278	59	96	50	0.90
Xylene	7.23	0.866	138-143	280-289	81	98	52	0.86
HI-SOL® 10	7.29	0.876	152-177	306-350	105	90	55	0.15
HI-SOL 70	7.14	0.857	163-202	325-395	105	70	95	0.10
HI-SOL 15	7.43	0.893	177-216	350-420	142	89	61	0.06

[1] n-Butyl Acetate = 1

Table 2.126: Chemcentral Solvents (Aliphatic and Aromatic) *(67)*

ALIPHATIC PETROLEUM NAPHTHAS*	A.P.I. Gravity 60/60°F	H_2O = 1 Specific Gravity 60/60°F	Pounds Per Gal. @ 60°F	Coeff. of Expan. Per °C	△Spec. Gravity Per °C	Refractive Index @ 20°C	Distillation Range @ 760 mm Hg		Vapor Press. @ 68°F (mm Hg)
							°C	°F	
HEPTANE	71	0.69	5.81	0.0011	.00066	1.3912	93.6-98.4	200.5-209	45.0
HEXANE	78.3	0.675	5.61	0.0015	.00077	1.3812	66-70.5	151-159	140.0
KEROSENE	41.4	0.8184	6.814	0.0009	.00080	1.4485	177-272	350-522	0.4
LACQUER DILUENT	57.3	0.7495	6.239	0.0011	.00066	1.4154	97-107	206-225	60.0
#360 SOLVENT	**51.7**	**0.772**	**6.423**	**0.0008**	**.00048**	**1.4258**	**157-179**	**315-353**	**2.8**
MINERAL SEAL OIL	37.3	0.8383	6.98	0.0009	.00059	1.4665	278-316	532-600	0.01
MINERAL SPIRITS	49.3	0.787	6.55	0.0009	.00057	1.4347	153-198	307-389	3.4
ODORLESS MINERAL SPIRITS	54.2	0.7620	6.344	0.0011	.00070	1.4240	179-198	354-388	0.5
RUBBER SOLVENT	71.6	0.700	5.83	0.0013	.00077	1.3908	42-135	107-275	180.0
STODDARD SOLVENT	**51.8**	**0.7720**	**6.427**	**0.0009**	**.00055**	**1.4278**	**156-198**	**312-387**	**2.0**
HEXSOLV	76.0	0.682	5.68	0.0013	.00075	1.3829	64-80	146-176	155.0
VM & P NAPHTHA	59.9	0.739	6.15	0.0011	.00068	1.4273	118-142	244-287	2.0
#460 SOLVENT	47.7	0.79	6.85	0.0009	.00059	1.4404	179-254	355-490	0.23
VM & P NAPHTHA 66	56.0	0.7547	6.283	0.0011	.00069		126-142	260-288	5.2
MINERAL SPIRITS 66	**52.0**	**0.7724**	**6.430**	**0.0009**	**.00055**	**1.4277**	**159-194**	**318-380**	**2.6**
#140 SOLVENT 66	48.8	0.785	6.541	0.0009	.00055	1.4340	191-203	376-397	0.5

ALIPHATIC PETROLEUM NAPHTHAS*	Evaporation Rate But. Ace = 1	Kauri Butanol Value cc.	Aniline Point °F Straight	Flash Point Tag C.C. °F	Explosive Limits % by Vol. in Air		Composition % By Volume			C_9+ Aromatic	Solubility Parameter
					Lower	Upper	FIA Saturates	Olefins	Aromatics (Tol.-Eth. Benz)		
HEPTANE	4.5	30	153	20	1.2	6.7	99.9	0	0.1	0	7.4
HEXANE	8.1	30.5	147	0	1.2	7.5	100	0	0	0	7.3
KEROSENE		34	144	148	1.0	8.0	80	1	0	19	7.2
LACQUER DILUENT	3.9	43	109	20	1.2	6.8	85	1	15	0	7.7
#360 SOLVENT	**0.21**	**33**	**152**	**105**	**1.0**	**6.0**	**99.8+**	**<1**	**0**	**<1**	**7.5**
MINERAL SEAL OIL	0.1	27.4	189	265**			97	0	0	3	7.2
MINERAL SPIRITS	0.12	37	132	104	0.7	6.0	93.1	0	0	6.9	7.5
ODORLESS MINERAL SPIRITS	0.2	27	185	129	1.0	6.0	98+	1	0	1	7.1
RUBBER SOLVENT	6.10	34	142	0	1.3	7.4	96	0	4	0	7.4
STODDARD SOLVENT	**0.21**	**33**	**156**	**108**	**0.7**	**6.0**	**99.7**	**0**	**0**	**0.3**	**7.6**
HEXSOLV	8.8	31	146	0	1.2	6.7	99+	0	<1	0	7.2
VM & P NAPHTHA	0.45	34	140	52	1.1	5.0	90.5	0	1.8	7.7	7.8
#460 SOLVENT	0.01	32	155	140	1.4	6.8	92	1	0	8	
VM & P NAPHTHA 66	1.0	35	143	40	0.9	6.0	99+	0	<1	0	7.6
MINERAL SPIRITS 66	**0.13**	**32**	**155**	**108**	**0.7**	**6.0**	**99.8+**	**<1**	**0**	**<1**	**7.6**
#140 SOLVENT 66	0.08	30	162	144	1.0	7.0	99.7	<1	0	<1	7.6

*The properties listed above for aliphatic petroleum naphthas and aromatic hydrocarbon solvents are typical only. Because these properties may vary by geographic area, it may be necessary to contact your CHEMCENTRAL representative for exact specifications of the specific product you purchase.

**Open Cup

AROMATIC HYDROCARBON SOLVENTS	A.P.I. Gravity 60/60°F	Specific Gravity 60/60°F	Pounds Per Gal. @ 60°F	Coeff. of Expan. Per °C	△Spec Gravity Per °C	Refractive Index @ 20°C	Distillation Range @ 760 mm Hg		Vapor Press. @ 20°C mm Hg	Evaporation Rate	
							°C	°F		Minutes	n-Butyl Ace. = 1
BENZENE	28.5	0.884	7.36	0.0012	.00093	1.5003	80-80.6	176-177	75	1.2	4.8
TOLUENE	30.8	0.872	7.26	0.0011	.00080	1.4973	110-111	230-232	38	2.7	1.5
XYLENE	31.0	0.871	7.25	0.0010	.00073	1.4970	138-140	281-284	9.5	10.8	0.75
SC #1	38.1	0.834	6.947	0.0009	.00059	1.4670	101.1-116	214-240	27.5		1.0
SC #2	**36.2**	**0.8438**	**7.026**	**0.0009**	**.00059**	**1.4768**	**137.8-153**	**280-308**	**5.2**		**0.12**
SC #3	33.0	0.860	7.158	0.0008	.00055	1.4897	180-199	356-390	2.0		0.12
SC #28	33.3	0.859	7.15	0.0009	.00061	1.4882	162-201	324-394			
SC #100	30.3	0.875	7.28	0.0008	.00055	1.4982	155-173	311-344	<1	21.0	0.19
SC #150	25.9	0.899	7.49	0.0008	.00059	1.5020	183-210	362-410	1	98.0	0.04
H.A.N. SOLVENT	**26.9**	**0.893**	**7.44**	0.0008	**.00059**		**160-293**	**320-560**	<1		

AROMATIC HYDROCARBON SOLVENTS	Kauri Butanol Value cc.	Aniline Point °F		Absolute Viscosity cps @ 25°C	Flash Point Tag C.C. °F	Explosive Limits % by Vol. in Air		Composition % By Volume				Solubility Parameters
		Straight	Mixed			Lower	Upper	FIA Saturates	Olefins	Aromatics (Tol-Eth. Benz)	C_9+ Aromatic	
BENZENE	107	-44	52.0	0.60	10	1.7	7.1	0.1	0	0	0	9.2
TOLUENE	105		48.0	0.567	45	1.2	7.0	0.02	0	99.98	0	8.9
XYLENE	98		51.0	0.616	80	1.0	7.0	0.1	0	25.7	74.2	8.9
SC #1	86.4		79.0		20	1.2	7.0	27.51	0	72.5	0	8.5
SC #2	**80**		**78.0**		**81**	**1.0**	**7.0**	**17.9**	**0**	**9.9**	**78.9**	**8.5**
SC #3	72.7		81.0		142	1.1	7.0	19.8	1.7	0	77.5	8.5
SC #28	75		86.0		119	1.0	6.0	25.0	0.9	0	75	8.5
SC #100	92		56.0	0.779	110	1.0	6.5	2.0	0	0	98	8.8
SC #150	92		59.7	1.20	150	0.9	6.5	2.0	0	0	98	8.7
H.A.N. SOLVENT	**78**		**82.4**		**140**		**6.5**	**19.0**	**1**	**0**	**80**	**8.7**

Table 2.127: Crowley Solvents *(60)*

METHYL NAPHTHALENE NO. 5

	Specifications		Typical	
Specific Gravity 60°/60°F	0.975/1.010		0.988	
Distillation Range:	°F	°C	°F	°C
IBP, Min.	400	204	440	227
FBP, Max.	600	315	550	288
Flash Point, PMCC, Min. (Non-Combustible)	200	93	215	102
Aromatic Content, Min.		95%		98%
Mixed Aniline Point, ASTM, Max.	61	16.1		11.8
Color, ASTM, Max.		-2		1.0
Color, Visual			Pale Straw	
Pour Point			15	-10

AROMATIC SOLVENT 58

Specific Gravity @ 60°F.	.9279/.9465
Distillation Range °F.	
IBP	375
5%	449
10%	465
50%	523
70%	564
90%	634
95%	666
EP	689
Flash Point °F.	240
\romatic Content	74%
Color	2.0
SSU Viscosity @ 100°F.	46.3
Pour Point °F.	-25

SAF-T-SOL 200

Specific Gravity @ 60/60°F	0.987
Distillation Range (ASTM D-850)	
5%	430°F
50%	555°F
90%	590°F
Aniline Point, Mixed ASTM	15°C
Color	Yellow
SSU Viscosity @ 100°F	40 secs
Pour Point	-60°F
Flash Point, COC	250°F
Aromatics	98%

Table 2.128: Dynaloy Solvents *(37)*

DESCRIPTION

Dynasolve 210 was developed to fill a widespread need for a solvent that would dissolve RTV silicones and silicone conformal coatings effectively at room temperature. Dynasolve 210 dissolves silicones quickly and effectively, but it contains methylene chloride, and may attack other polymers or coatings, such as epoxies and urethanes. Dynasolve 220, 225, and 230, while not quite as fast as Dynasolve 210, contain no chlorinated solvents and are more selective. In most cases, Dynasolve 230 is fastest, followed by Dynasolve 225, and then Dynasolve 220.

Dynasolve 210, 220, 225 and 230, when not contaminated by water, will not attack metal or metal components, with the exception of aluminum. However, aluminum may be etched after extended immersion in these Dynasolves. Contamination of these Dynasolves with water will result in the formation of acids that can attack most metals and other substrates. Test data shows that mu-metal was untouched after a 24 hour immersion in Dynasolve 210. Dynasolve 220, 225, and 230 will not attack acrylic or polycarbonate.

TYPICAL PROPERTIES

	DYNASOLVE 210	DYNASOLVE 220	DYNASOLVE 225	DYNASOLVE 230
Color	Amber	Amber	Amber	Amber
Specific Gravity	1.272	0.828	0.806	0.707
Boiling Point	104°F	311-348°F	235-290°F	202-222°F
Flash Point	None	110°F	52°F	16°F
pH	2.14	1.70	1.60	1.30

DYNASOLVE CU-5

SAFETY CLEANING SOLVENT FOR URETHANES

DESCRIPTION

Dynasolve CU-5 is a unique solvent that was developed for use in cleaning urethane residues and crystallized isocyanates from various types of polyurethane processing equipment.

TYPICAL PROPERTIES

Color:	Clear
Specific Gravity:	1.060
Boiling Point:	202°C
Flash Point:	191°F CC
pH:	4 - 6

DYNASOLVE CU-6

SAFETY CLEANING SOLVENT FOR URETHANES

DESCRIPTION

Dynasolve CU-6 is a unique solvent that was developed as a non-gelling, higher flash point version of Dynasolve CU-5.

TYPICAL PROPERTIES

Color:	Clear
Specific Gravity:	1.055
Boiling Point:	202°C
Flash Point:	210°F CC
pH:	4 - 6

(continued)

Table 2.128: (continued)

DYNASOLVE XD 16-4

SAFETY SOLVENT FOR REMOVAL OF SILICONE OILS AND UNCURED SILICONE POLYMERS

DESCRIPTION

Dynasolve XD 16-4 is an experimental solvent that was developed for removal of silicone oils and uncured silicone polymers from molds, molded parts, and processing equipment.

TYPICAL PROPERTIES

Color:	Light Amber
Specific Gravity:	1.032
Boiling Point:	>300°F
Flash Point:	262°F
pH:	N/A

DYNASOLVE XD 22-1

SAFETY SOLVENT FOR CLEANING AND DEGREASING

DESCRIPTION

Dynasolve XD 22-1 is an experimental solvent that was developed for use in cleaning and degreasing applications. Dynasolve XD 22-1 is a non-chlorinated, non-flammable*, non-carcinogenic, non-ozone depleting solvent

TYPICAL PROPERTIES

Color:	Clear
Specific Gravity:	0.780
Boiling Point:	360°F
Flash Point:	143°F CC
pH:	N/A

DYNASOLVE XD 27-2

SAFETY SOLVENT FOR CIRCUIT BOARD CLEANING AND DEFLUXING

DESCRIPTION

Dynasolve XD 27-2 is an experimental solvent that was developed for cleaning and defluxing of printed circuit boards. Dynasolve XD 27-2 is a non-chlorinated, non-flammable*, non-carcinogenic, non-ozone depleting solvent designed as a replacement for CFCs.

TYPICAL PROPERTIES

Color:	Transparent Yellow
Specific Gravity:	1.000
Boiling Point:	363°F
Flash Point:	191°F CC
pH:	8 - 9

Table 2.128: (continued)

SOLVENT GUIDE UPDATE

DYNASOLVE DF-1	A replenisher concentrate for Dynaflush. When added to vacuum distilled or spent Dynaflush, will restore its efficiency and loading capacity to original levels.
DYNASOLVE M-35	A low-toxicity, low volatility solvent for general cleaning applications. Especially suited for use in cleaning of uncured polymers, such as epoxies, urethanes, and silicones. Also very effective for dissolving cured cyanoacrylate instant glues.
DYNASOLVE XD 16-3	An experimental aqueous solution for use in the removal of silicone oils and uncured silicone polymers from molds, molded parts, and processing equipment. Especially effective for cleaning mold release residue from plastic molded parts, as it will not harm the surface of the parts.

Table 2.129: Eastman Solvents and Diluents *(41)*

ACTIVE SOLVENTS	Evaporation Rate nBuOAc = 1	Evaporation Rate Ether = 1	Formula	Viscosity, cP 8% *RS* ½-s NC @25°C	Viscosity, cP 8% CAB-381-0.5 @ 25°C	Neat Viscosity cP	Neat Viscosity °C	Dilution Ratio[b] Toluene	Dilution Ratio[b] *VM&P* Naphtha	Blush Resistance % RH @ 80°F	Specific Gravity @ 20°/20°C	Weight/Volume @ 20°C Lb/Gal	Weight/Volume @ 20°C Kg/L	Flash Point TCC, °F	Freezing Point, °F
METHYLENE CHLORIDE	14.5	0.8	CH_2Cl_2	Ins[g]	22	0.33	25	—		—	1.320[h]	10.98[i]	1.31[i]	None	-142
TETRAHYDROFURAN	6.3	1.9	$\overline{OCH_2CH_2CH_2CH_2}$	16	13	0.48	20	2.8	1.0	50	0.889	7.41	0.89	6	-163
ACETONE	[illegible]	[illegible]	CH_3COCH_3		8	0.33	20	[illegible]	[illegible]	20	0.792	6.60	0.79	4	-138
METHYL ACETATE	5.3	[illegible]	CH_3COOCH_3	[illegible]	14	0.41	20	2.9	[illegible]	20	0.940	7.70	0.94	9	-144
ETHYL ACETATE, 85%–88%	**4.2**	**2.9**	$CH_3COOC_2H_5$	**17**	**15**	**0.49**	**25**	**3.3**	**1.2**	**38**	**0.884**	**7.36**	**0.88**	**27**	**−118**
ETHYL ACETATE, 99%	**4.1**	**3.0**	$CH_3COOC_2H_5$	**20**	**15**	**0.45**	**25**	**3.1**	**1.1**	**39**	**0.901**	**7.51**	**0.90**	**24**	**−118**
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ISOPROPYL ACETATE	3.0	4.0	$CH_3COOCH(CH_3)_2$	22	17	0.60	20	3.0	[illegible]	62	0.873	7.26	0.87	35	-99
METHYL n-PROPYL KETONE	**2.3**	**5.3**	$CH_3COC_3H_7$	**14**	**13**	**0.68**	**25**	**3.9**	**1.0**	**70**	**0.807**	**6.74**	**0.81**	**46**	**−123**
n-PROPYL ACETATE	**2.3**	**5.3**	$CH_3COOC_3H_7$	**22**	**18**	**0.58**	**20**	**3.2**	**1.5**	**65**	**0.889**	**7.39**	**0.89**	**55**	**−134**
METHYL ISOBUTYL KETONE	1.6	7.6	$CH_3COCH_2CH(CH_3)_2$	[illegible]	15	0.60	20	[illegible]	[illegible]	78	0.802	6.67	0.80	60	-119
ISOBUTYL ACETATE	1.4	8.6	$CH_3COOCH_2CH(CH_3)_2$	[illegible]	28	0.70	20	2.7	[illegible]	80	0.870	7.25	0.87	69	-146
2-NITROPROPANE	1.1	11.0	$CH_3CHNO_2CH_3$	60	27	0.77	20	1.2	0.4	82	0.988	8.23	0.99	82	−132
n-BUTYL ACETATE	**1.0**	**12.1**	$CH_3COOC_4H_9$	**30**	**28**	**0.73**	**20**	**2.7**	**1.2**	**83**	**0.883**	**7.35**	**0.88**	**81**	**−101**
EASTMAN PM	0.7	17.3	$CH_3OCH_2CH(CH_3)OH$	80	49	1.90	20	5.2	0.9	56	0.923	7.69	0.92	91	-139
METHYL ISOAMYL KETONE	0.5	24.2	$CH_3COC_2H_4CH(CH_3)_2$	25	20	0.73	25	4.1	1.2	89	0.813	6.76	0.81	96	-101
METHYL AMYL ACETATE	0.5	24.2	$CH_3COOCH(CH_3)C_4H_9$	54	0	0.98	25	1.7	1.0	92	0.858	7.14	0.86	96	—
***EASTMAN* PM ACETATE**	**0.4**	**30.2**	$CH_3COOCH(CH_3)CH_2OCH_3$	**65**	**43**	**1.07**	**25**	**2.6**	**0.8**	**92**	**0.970**	**8.06**	**0.97**	**114[k]**	**<−89**
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]				[illegible]	0.876	7.29	[illegible]	[illegible]	[illegible]
METHYL n-AMYL KETONE	0.4	30.2	$CH_3COC_5H_{11}$	[illegible]	20	0.77	25	3.9	[illegible]	93	0.818	6.80	0.82	102	-27
ISOBUTYL ISOBUTYRATE	**0.4**	**30.2**	$(CH_3)_2CHCOOCH_2CH(CH_3)_2$	**100**	**Ins[g]**	**0.85**	**25**	**1.5**	**0.8**	**92**	**0.855**	**7.13**	**0.86**	**104**	**−112**
ETHYLENE GLYCOL ETHYL ETHER	0.3	40.3	$C_2H_5OC_2H_4OH$	73	53	2.10	20	5.0	1.1	59	0.931	7.75	0.93	110	−137
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	0.948	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				0.872[h]	[illegible]	[illegible]	[illegible]	[illegible]
PROPYLENE GLYCOL PROPYL ETHER	0.2	60.5	$C_3H_7OCH_2CH(CH_3)OH$	95	Ins	2.80	20	—	[illegible]	—	0.886	7.38	0.88	119	-112
ETHYLENE GLYCOL ETHYL ETHER ACETATE	0.2	60.5	$CH_3COOC_2H_4OC_2H_5$	66	45	1.30	20	2.5	0.9	94	0.973	8.11	0.96	130	− 78
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48	[illegible]	[illegible]	[illegible]		[illegible]	0.874	[illegible]	[illegible]	[illegible]	[illegible]
DIISOBUTYL KETONE	0.2	60.5	$(CH_3)_2CHCH_2COCH_2CH(CH_3)_2$	46	Ins	0.95	20	[illegible]	0.8	95	0.811	6.76	0.81	120	-43

(continued)

Table 2.129: (continued)

ACTIVE SOLVENTS	Vapor Pressure Torr	°C	KPa @ 55°C[c]	Surface Tension Dyne/Cm	°C	Boiling Range @ 760 Torr, °C	Solubility @ 20°C Wt % In Water	Water In	Azeotrope BP, °C	Wt % Water[d]	Autoignition Temperature, °C	Refractive Index Value	°C	Electrical Resistance,[e] Megohms	Hansen Solubility Parameters[f] Total	Nonpolar	Polar	Hydrogen Bonding	Gram Molecular Weight	TLV PPM 1992
METHYLENE CHLORIDE	340.0	20		26.5	20	39–41	1.4	[illegible]	[illegible]	1.5	662	1.4242	20	1.5	[illegible]	8.9	[illegible]	3.0	84.90	50
TETRAHYDROFURAN	143.0	20		26.4	25	65–67	Complete	Complete	[illegible]	4.6	321	1.4073	20	2.0	9.5	8.2	2.8	3.9	72.11	200
ACETONE	[illegible]	20	[illegible]	[illegible]	20	55.5–57.1	Complete	Complete	None		538	1.3591	20	[illegible]	[illegible]	[illegible]	[illegible]	3.4	58.08	750
METHYL ACETATE	[illegible]	20	[illegible]	25.8	20	55.8–58.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3600	20	0.4	[illegible]	[illegible]	[illegible]	3.7	74.09	200
ETHYL ACETATE, 85%–88%	**75.0**	**20**	—	**24.2**	**20**	**71–79**	**7.4**	**3.1**	**70.4**	**8.5**	**466**	**1.3693**	**20**	**0.3**	—	—	—	—	**88.11**	—
ETHYL ACETATE, 99%	**75.0**	**20**	**45.9**	**23.9**	**20**	**75.5–78**	**7.4**	**3.3**	**70.4**	**8.5**	**485**	**1.3718**	**20**	**20.0**	**8.8**	**7.7**	**2.6**	**3.5**	**88.11**	**400**
METHYL ETHYL KETONE				[illegible]	[illegible]	[illegible]					[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
ISOPROPYL ACETATE	[illegible]	20	[illegible]	22.1	20	85–90	[illegible]	[illegible]	[illegible]	[illegible]	479	1.3772	20	>20	[illegible]	[illegible]	[illegible]	4.0	102.13	250
METHYL n-PROPYL KETONE	**27.8**	**20**	**19.2**	**26.6**	**20**	**101–105**	**3.1**	**4.2**	**83.3**	**19.5**	**449**	**1.3902**	**20**	**0.3**	**8.9**	**7.8**	**3.7**	**2.3**	**86.13**	**200**
n-PROPYL ACETATE	**23.0**	**20**	**18.9**	**24.3**	**20**	**99–10[illegible]**	**2.3**	**2.6**	**82.4**	**14.0**	**457**	**1.3847**	**20**	**>20**	**8.6**	**7.5**	**2.1**	**3.7**	**102.14**	**200**
METHYL ISOBUTYL KETONE	[illegible]	20	[illegible]	23.6	20	114–117	[illegible]	[illegible]	[illegible]	24.3	449	1.3958	20	0.4	[illegible]	[illegible]	3.0	2.0	100.16	50
ISOBUTYL ACETATE	[illegible]	20	10.7	23.7	20	112–119	[illegible]	[illegible]	[illegible]	16.5	427	1.3895	20	>20	[illegible]	[illegible]	1.6	3.1	116.20	150
2-NITROPROPANE	18.0	20	—	29.9	20	119–122	1.7	0.6	88.6	29.4	428	1.3944	20	<0.1	10.1	7.9	5.9	2.0	89.09	10
n-BUTYL ACETATE	**10.0**	**20**	**7.4**	**25.1**	**20**	**122–129**	**0.7**	**1.6**	**90.2**	**28.7**	**407**	**1.3941**	**20**	**>20**	**8.5**	**7.7**	**1.8**	**3.1**	**116.16**	**150**
***EASTMAN* PM**	[illegible]	20	[illegible]	28.3	25	121[f]	Complete	Complete			—	1.4036	20	0.4	[illegible]	[illegible]	[illegible]	5.7	90.12	100
METHYL ISOAMYL KETONE	[illegible]	20	3.7	25.8	20	141–148	[illegible]	[illegible]	[illegible]	44.0	424	1.4078	20	0.6	[illegible]	7.6	2.8	2.0	114.19	50
METHYL AMYL ACETATE	3.8	20	[illegible]	22.6	20	146–150	[illegible]	0.6	94.8	36.7	—	1.4008	20	>20	[illegible]	[illegible]	[illegible]	—	144.21	—
***EASTMAN* PM ACETATE**	**3.7**	**20**	**3.0**	**26.4**	**20**	**140–150**	**20.0**	**5.9**	—	—	**354**	**1.3995**	**20**	**5.0**	**9.4**	**7.6**	**2.7**	**4.8**	**132.20**	—
AMYL ACETATE, PRIMARY	[illegible]			28.5	20	[illegible]				[illegible]		[illegible]	[illegible]	[illegible]					130.19	[illegible]
METHYL n-AMYL KETONE	2.14	20	2.8	26.1	20	147–153	[illegible]	[illegible]	95.0	48.0	393	1.4080	20	0.4	[illegible]	[illegible]	2.8	2.0	114.19	50
ISOBUTYL ISOBUTYRATE	**3.2**	**20**	**3.3**	**23.2**	**20**	**144–151**	**<0.1**	**<0.2**	**95.5**	**39.4**	**432**	**1.3987**	**20**	**>20**	**8.1**	**7.4**	**1.4**	**2.9**	**144.22**	—
ETHYLENE GLYCOL ETHYL ETHER	3.8	20		29.3	20	134–136	Complete	Complete	98.2	87.0	238	1.4076	20	[illegible]	11.5	7.9	4.5	7.0	90.12	5
CYCLOHEXANONE				27.7	20	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	2.5	98.14	[illegible]
PROPYLENE [illegible]	[illegible]			24.2	25	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]				[illegible]	[illegible]	5.3	132.20	
PROPYLENE GLYCOL PROPYL ETHER	[illegible]	20	—	27.0	25	149.8[illegible]	Complete	Complete	[illegible]	—	—	1.4121	20	[illegible]	9.5	7.7	3.4	4.5	118.18	[illegible]
ETHYLENE GLYCOL ETHYL ETHER ACETATE	[illegible]	20	—	28.2	20	150–160	[illegible]	[illegible]	[illegible]	45.0	382	1.4030	20	4.0	9.7	7.8	2.3	5.2	132.16	5
MIXED HEXYL ACETATES	[illegible]			25.0	20	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	2.9	[illegible]	
DIISOBUTYL KETONE	1.4	20	1.4	24.6	20	163–17[illegible]	[illegible]	[illegible]	[illegible]	51.9	396	1.4150	20	0.4	[illegible]	7.6	1.8	2.0	142.23	25

Table 2.129: (continued)

ACTIVE SOLVENTS	Evaporation Rate nBuOAc = 1	Evaporation Rate Ether = 1	Formula	Viscosity, cP 8% RS ½-s NC @25°C	Viscosity, cP 8% CAB-381-0.5 @ 25°C	Neat Viscosity cP	Neat Viscosity °C	Dilution Ratio[b] Toluene	Dilution Ratio[b] VM&P Naphtha	Blush Resistance % RH @ 80°F	Specific Gravity @ 20°/20°C	Weight/Volume @ 20°C Lb/Gal	Weight/Volume @ 20°C Kg/L	Flash Point TCC, °F	Freezing Point, °F
DIMETHYL FORMAMIDE	0.2	60.5	$CHCON(CH_3)_2$	17	33	0.80	25	—	—	—	0.951	7.92	0.95	136	−78
***EASTMAN* EP**	**0.2**	**60.5**	$C_3H_7OC_2H_4OH$	**86**	**Ins**	**2.42**	**25**	**4.0**	**2.0**	**90**	**0.913**	**7.59**	**0.91**	**120**	**<−130**
DIAC[illegible]	0.12	100.8	$(CH_3)_2C(OH)CH$[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	76	0.940	[illegible]	[illegible]	[illegible]	[illegible]
EEP (ETHYL 3-ETHOXYPROPIONATE)	0.12	100.8	$C_2H_5OC_3H_4O_2C_2H_5$	62	54	[illegible]20	25	[illegible]	0.6	94	0.950	7.91	0.95	136[h]	<−58
PROPYLENE GLYCOL BUTYL ETHER	0.08	151.3	$C_4H_9OCH_2CH(CH_3)OH$	124	Ins	3.40	20	1.9	0.9	96	0.884	7.37	0.88	138	−148
***EASTMAN* EB**	**0.09**	**136.0**	$C_4H_9OC_2H_4OH$	**101**	**Ins**	**6.40**	**20**	**3.4**	**2.1**	**96**	**0.902**	**7.51**	**0.90**	**143**	**−103**
N METHYL [illegible]	0.04	302.5	C_5H_9NO	48	[illegible]	[illegible]	[illegible]				1.027[h]	[illegible]	[illegible]	[illegible]	[illegible]
MIXED [illegible]	0.03	403.4	Mixture			[illegible]	[illegible]	[illegible]	[illegible]		0.875	[illegible]	[illegible]	[illegible]	[illegible]
***EASTMAN* EB ACETATE**	**0.03**	**403.4**	$CH_3COOC_2H_4OC_4H_9$	**88**	**65**	**1.80**	**20**	**1.8**	**1.2**	**95**	**0.941**	**7.84**	**0.94**	**160**	**−83**
2-ETHYLHEXYL ACETATE	**0.04**	**403.4**	$CH_3COOCH_2CH(C_2H_5)C_4H_9$	**90**	**Ins**	**1.50**	**20**	**1.4**	**0.9**	**94**	**0.873**	**7.27**	**0.87**	**160**	**−135**
DIPROPYLENE [illegible]	0.02	605.1	$CH_3O(CH_2CH(CH$[illegible]	225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	90	0.951	[illegible]	[illegible]	[illegible]	[illegible]
EASTMAN C-11 KETONE	0.02	605.1	Mixture	65	Ins	2.12	25	2.3	1.0	96	0.840	7.02	0.84	184[k]	11
ISOPHORONE	0.02	605.1	$\overline{OCHC:C(CH_3)CH_2C(CH_3)_2CH_2}$	110	110	2.60	20	6.2	1.2	97	0.922	7.67	0.92	179	17
ETHYLENE GLYCOL DIACETATE	**0.02**	**605.1**	$(CH_3COOCH_2)_2$	**220**	**160**	**2.90**	**20**	**1.4**	**—**	**96**	**1.107**	**9.22**	**1.11**	**191**	**−43**
EASTMAN DM	0.02	605.1	$CH_3(OC_2H_4)_2OH$	174	160	3.90	20	2.3	imm[m]	76	1.023	8.51	1.02	191	−121
EASTMAN DE	0.02	605.1	$C_2H_5(OC_2H_4)_2OH$	180	140	4.50	20	1.9	imm[m]	76	0.990	8.25	0.99	195	−130
***EASTMAN* DP**	**0.01**	**1,210.2**	$C_3H_7(OC_2H_4)_2OH$	**190**	**Ins**	**4.12**	**25**	**4.6**	**1.6**	**—**	**0.963**	**8.04**	**0.96**	**200**	**<−90**
ETHYLENE GLYCOL HEXYL ETHER	0.01	1,210.2	$C_6H_{13}OC_2H_4OH$	120	Ins	5.20	20	2.4	1.5	96	0.889	7.40	0.89	179	−58
EASTMAN DE ACETATE	0.008	1,512.7	$CH_3COO(C_2H_4O)_2C_2H_5$	162	110	2.80	20	2.2	0.6	92	1.012	8.42	1.01	225[i]	−13
DIBASIC [illegible]	0.007	1,728.9	$CH_3COO(CH_2)$[illegible]	200	[illegible]	[illegible]	[illegible]			—	1.092	[illegible]	[illegible]	[illegible]	[illegible]
***EASTMAN* DB**	**0.004**	**4,034.0**	$C_4H_9(OC_2H_4)_2OH$	**205**	**Ins**	**4.74**	**25**	**3.9**	**1.9**	**85**	**0.955**	**7.94**	**0.96**	**232[n]**	**−105**
***EASTMAN* EEH**	**0.003**	**4,034.0**	$C_4H_9CH(C_2H_5)CH_2OC_2H_4OH$	**Ins**	**Ins**	**7.01**	**25**	**—**	**—**	**—**	**0.892**	**7.42**	**0.89**	**208[k]**	**<−50**
EASTMAN DB ACETATE	0.002	6,051.0	$CH_3COO(C_2H_4O)_2C_4H_9$	186	140	3.20	25	1.8	0.9	96	0.980	8.16	0.98	240[n]	26
PROPYLEN[illegible]	0.002	6,051.0	[illegible]		[illegible]	[illegible]	[illegible]				1.063[i]	[illegible]		[illegible]	[illegible]
***TEXANOL* ESTER-ALCOHOL**	**0.002**	**6,051.0**	$(CH_3)_2CHCOOCH_2C(CH_3)_2CHOHCH(CH_3)_2$	**1,115**	**Ins**	**18.30**	**20**	**—**	**—**	**—**	**0.950**	**7.90**	**0.95**	**248[n]**	**−58**
MIXED TRIDECYL ACETATE ESTERS	0.001	12,100.0	Mixture	—	—	4.63	25	—	—	—	0.880	7.30	0.88	261	<−60

(continued)

Table 2.129: (continued)

ACTIVE SOLVENTS	Vapor Pressure Torr	°C	KPa @ 55°C[c]	Surface Tension Dyne/Cm	°C	Boiling Range @ 760 Torr, °C	Solubility @ 20°C Wt % In Water	Water In	Azeotrope BP, °C	Wt % Water[d]	Autoignition Temperature, °C	Refractive Index Value	°C	Electrical Resistance,[e] Megohms	Hansen Solubility Parameters[f] Total	Nonpolar	Polar	Hydrogen Bonding	Gram Molecular Weight	TLV PPM 1992
DIMETHYL FORMAMIDE	3.7	20	—	35.2	25	153[i]	Complete	Complete	—	—	445	1.4282	25	—	[illegible]	8.5	6.7	5.5	73.09	10
***EASTMAN* EP**	**1.3**	**20**	**2.2**	**27.9**	**25**	**149.5–153.5**	**Complete**	**Complete**	**98.5**	**73.0**	**235**	**1.4136**	**20**	**0.1**	11.1	**7.9**	**4.2**	**6.6**	**104.15**	**—**
DIACETONE ALCOHOL	[illegible]			[illegible]	[illegible]	[illegible]	Complete	Complete	[illegible]	[illegible]	[illegible]	1.4234	20	[illegible]	[illegible]		[illegible]	5.3	116.16	50
EEP (ETHYL 3-ETHOXYPROPIONATE)	1.5	25	1.2	27.0	23	165–172	2.9	2.2	97.0	63.0	377	1.4074	20	20	[illegible]	7.9	1.6	4.3	146.19	—
PROPYLENE GLYCOL BUTYL ETHER	0.6	20	—	27.4	25	170.2[j]	6.4	15.5	—	—	—	1.4173	20	0.4	9.6	7.5	2.2	4.5	132.20	—
***EASTMAN* EB**	**0.6**	**20**	**0.97**	**26.6**	**20**	**169–172.5**	**Complete**	**Complete**	**98.8**	**79.2**	**238**	**1.4193**	**20**	**<0.2**	**10.2**	**7.8**	**2.5**	**6.0**	**118.17**	**25**
N-METHYL-2-PYRROLIDONE	[illegible]	[illegible]		[illegible]	25	[illegible]	Complete	Complete			[illegible]	1.4690	25		[illegible]	[illegible]	[illegible]	3.5	99.10	—
MIXED OCTYL ACETATE ESTERS	[illegible]	[illegible]		[illegible]	20	[illegible]	0.02	[illegible]			398	1.4200	20	[illegible]				—	172.00	—
***EASTMAN* EB ACETATE**	**0.29**	**20**	**0.77**	**30.3**	**20**	**186–194**	**1.1**	**1.6**	**98.8**	**71.9**	**340**	**1.4142**	**20**	**>20**	**8.9**	**7.5**	**2.2**	**4.3**	**160.21**	**—**
2-ETHYLHEXYL ACETATE	**0.40**	**20**	**0.36**	**25.8**	**20**	**199–205**	**0.03**	**0.6**	**99.0**	**73.5**	**268**	**1.4201**	**20**	**>20**	**8.2**	**7.7**	**1.4**	**2.5**	**172.27**	**—**
DIPROPYLENE GLYCOL METHYL ETHER	[illegible]	[illegible]		[illegible]	25	[illegible]	Complete	Complete			—	1.4205	25	[illegible]		[illegible]	2.8	5.5	148.20	100
EASTMAN C-11 KETONE	—	—	0.17	27.5	24	200–240	0.2	0.9	—	—	238	1.4355	20	1.5	8.2	7.9	1.0	2.0	—	—
ISOPHORONE	0.18	20	—	32.3	20	210–218	1.2	4.3	99.5	83.9	460	1.4781	20	<0.1	[illegible]	8.1	4.0	3.6	138.20	5
ETHYLENE GLYCOL DIACETATE	**0.2**	**20**	**0.18**	**33.7**	**20**	**187–193**	**16.4**	**7.6**	**99.7**	**84.6**	**482**	**1.4159**	**20**	**5.0**	**9.5**	**7.9**	**2.3**	**4.8**	**146.15**	**—**
EASTMAN DM	0.2	20	1.4	34.8	25	191–198	Complete	Complete	—	—	240	1.4268	20	<0.2	[illegible]	7.9	3.8	6.2	120.15	—
EASTMAN DE	0.12	20	0.49	32.2	20	198–204	Complete	Complete	None	—	205	1.4260	20	<0.2	[illegible]	7.9	3.8	6.2	134.17	—
***EASTMAN* DP**	**0.05**	**20**	**0.11**	**32.3**	**20**	**202–216**	**Complete**	**Complete**	**—**	**—**	**204**	**1.4290**	**20**	**0.1**	**10.2**	**7.8**	**3.5**	**5.5**	**148.20**	**—**
ETHYLENE GLYCOL HEXYL ETHER	<1.0	20	—	—	—	208.1[illegible]	1.0	18.8	99.7	91.0	—	1.4290	20	0.3	—	—	—	—	146.23	—
EASTMAN DE ACETATE	0.05	20	0.16	31.7	25	214–22	Complete	Complete	99.2	76.0	360	1.4220	20	3.0	9.4	7.9	2.5	4.5	176.21	—
DIBASIC ESTERS	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	1.4220	20	[illegible]		[illegible]	[illegible]	4.1	159.00	—
***EASTMAN* DB**	**0.02**	**20**	**0.04**	**30.0**	**20**	**230–235**	**Complete**	**Complete**	**None**	**—**	**205**	**1.4316**	**20**	**<0.3**	**10.0**	**7.8**	**3.4**	**5.2**	**162.23**	**—**
***EASTMAN* EEH**	**0.08**	**20**	**0.06**	**27.6**	**20**	**224–275**	**0.2**	**6.2**	**—**	**—**	**—**	**1.4361**	**20**	**1.5**	**8.4**	**7.8**	**2.0**	**2.5**	**—**	**—**
EASTMAN DB ACETATE	0.04	20	0.02	30.0	20	235–250	6.5	3.7	99.8	92.0	349	1.4239	20	>20	9.0	7.8	2.0	4.0	204.27	—
PROPYLENE GLYCOL PHENYL ETHER	[illegible]	[illegible]		[illegible]	25	242.7						—				[illegible]	[illegible]	5.6	152.20	—
***TEXANOL* ESTER-ALCOHOL**	**0.01**	**20**	**0.02**	**28.9**	**20**	**255–260.5**	**Ins[g]**	**0.9**	**—**	**—**	**393**	**1.4423**	**20**	**>20**	**9.3**	**7.4**	**3.0**	**4.8**	**216.30**	**—**
MIXED TRIDECYL ACETATE ESTERS	0.03	20	—	28.0	20	240–285	0.0	0.2	—	—	302	1.4380	20	>20	8.0	7.7	1.2	2.0	242.00	—

Table 2.129: (continued)

LATENT SOLVENTS	Evaporation Rate nBuOAc = 1	Evaporation Rate Ether = 1	Formula	Viscosity, cP 8% RS ½-s NC @25°C	Viscosity, cP 8% CAB-381-0.5 @ 25°C	Neat Viscosity cP	Neat Viscosity °C	Dilution Ratio[b] Toluene	Dilution Ratio[b] VM&P Naphtha	Blush Resistance % RH @ 80°F	Specific Gravity @ 20°/20°C	Weight/Volume @ 20°C Lb/Gal	Weight/Volume @ 20°C Kg/L	Flash Point TCC, °F	Freezing Point, °F
METHYL ALCOHOL	3.5	3.5	CH_3OH	20		0.60	20	2.2	0.5		0.792	6.60	0.79	50	—
TECSOL INDUS. AND PROPRIETARY SOLVENTS	1.7–1.9	—	C_2H_5OH			1.2–1.5	20				0.789–0.820	6.57–6.83	0.79–0.82	50	−173
ISOPROPYL ALCOHOL, 99%	1.7	7.1	$(CH_3)_2CHOH$			2.40	20				0.786	6.54	0.78	55	−127
n-PROPYL ALCOHOL	1.0	12.1	C_3H_7OH			2.00	25				0.804	6.71	0.80	74	−197
SECONDARY BUTYL ALCOHOL	0.9	13.4	$CH_3CH_2CHOHCH_3$			2.90	25				0.810	6.73	0.81	72	—
ISOBUTYL ALCOHOL	**0.6**	**20.2**	$CH_3CH(CH_3)CH_2OH$			**4.00**	**20**				**0.803**	**6.68**	**0.80**	**85**	**−162**
n-BUTYL ALCOHOL	0.5	24.2	C_4H_9OH			3.00	20				0.811	6.75	0.81	97	−129
METHYL ISOBUTYL CARBINOL	0.3	40.3	$CH_3CHOHCH_2CH(CH_3)_2$			3.80	25				0.805[i]	6.69	0.80	103	−130
AMYL ALCOHOL (MIXED PRIMARY ISOMERS)	0.3	40.3	$C_5H_{11}OH$			4.30	20				0.814[h]	6.77[i]	0.81[i]	—	−130
CYCLOHEXANOL	0.05	242.0	$CH_2(CH_2)_4CHOH$			52.70	25				0.947[b]	7.87[i]	0.94[i]	-	—
2-ETHYLHEXANOL	0.01	1,210.2	$C_4H_9CH(C_2H_5)CH_2OH$			7.70	25				0.833	6.94	0.83	164	−94

LATENT SOLVENTS	Vapor Pressure Torr	Vapor Pressure °C	Vapor Pressure KPa @ 55°C[c]	Surface Tension Dyne/Cm	Surface Tension °C	Boiling Range @ 760 Torr, °C	Solubility @ 20°C Wt % In Water	Solubility @ 20°C Wt % Water In	Azeotrope BP, °C	Azeotrope Wt % Water[d]	Autoignition Temperature, °C	Refractive Index Value	Refractive Index °C	Electrical Resistance,[e] Megohms	Hansen Solubility Parameters[f] Total	Hansen Nonpolar	Hansen Polar	Hansen Hydrogen Bonding	Gram Molecular Weight	TLV PPM 1992
METHYL ALCOHOL	100.0	21.2	69.0	22.6	20	64–65	Complete	Complete	None	—	463	1.3286	20	<0.1	14.5	7.4	6.0	10.9	32.04	200
TECSOL INDUS. AND PROPRIETARY SOLVENTS[o]	—	—	37.6[p]	22.4	20	74–82	Complete[q]	Complete[q]	78.1	4.0	419	1.3614	20	<0.1	13.0	7.7	4.3	9.5	46.07	—
ISOPROPYL ALCOHOL, 99%	32.8	20	30.8	21.3	20	80.8–83.3	Complete	Complete	80.3	12.6	360	1.3776	20	<0.2	11.5	7.7	3.0	8.0	60.10	400
n-PROPYL ALCOHOL	14.5	20	15.7	23.8	20	96–98	Complete	Complete	87.0	28.3	413	1.3856	20	<0.2	12.0	7.8	3.3	8.5	60.10	200
SECONDARY BUTYL ALCOHOL	12.0	20	—	24.0	20	98–101	20.6	30.7	87.0	26.8	406	1.3972	20	<0.2	10.8	7.7	2.8	7.1	74.12	100
ISOBUTYL ALCOHOL	**9.0**	**20**	**9.5**	**22.8**	**20**	**106–109**	**9.5**	**14.3**	**89.8**	**33.0**	**416**	**1.3955**	**20**	**<0.2**	**11.1**	**7.4**	**2.8**	**7.8**	**74.12**	**50**
n-BUTYL ALCOHOL	5.5	20	6.1	24.6	20	116–119	7.9	20.8	92.7	42.5	355	1.3993	20	<0.2	11.3	7.8	2.8	7.7	74.12	50
METHYL ISOBUTYL CARBINOL	[illegible]	20		22.8	20	[illegible]	[illegible]	[illegible]	94.3	43.3	[illegible]	[illegible]	20	0.2	9.7	7.5	1.6	6.0	102.18	25
AMYL ALCOHOL (MIXED PRIMARY ISOMERS)	2.9	20	—	23.8	20	127–137	1.7	9.2	95.8	54.4	—	1.4014	20	0.2	—	—	—	—	88.15	—
CYCLOHEXANOL	0.9	20	—	35.1	20	160–162	0.1	11.8	97.8	80.0	300	1.4656	20	0.4	11.0	8.5	2.0	6.6	100.16	50
2-ETHYLHEXANOL	0.05	20	0.26	28.7	20	182–186	0.1	2.6	99.1	80.0	288	1.4316	20	>20	9.9	7.8	1.6	5.8	130.20	-

Table 2.130: Exxon Hydrocarbon Solvents *(8)*

Product	Source	Distillation Range, °C	°F	Flash Point, TCC[a] °C	°F	Specific Gravity, @ 15.6/15.6°C	Density @ 60°F lb/gal	Aniline Pt., ASTM D 611 °C	°F	KB Value	Evaporation Rate, n-BuAc=100	Surface Tension, Dynes/cm	Hildebrand Solubility Parameter	Composition, Wt % Cyclo-paraffin	Paraffin	Aromatics	OEL, ppm	CAS Registry Number
ALIPHATICS																		
1520 Naphtha*	SA	64-94	147-201	<-18	<0	0.67	5.61	[illegible]	155	28	560	18.2	[illegible]	[illegible]	98	<0.5	100	[illegible]
RS Naphtha*	SA	66-102	151-216	<-18	<0	0.69	5.75	8	137	34	460	19.1	[illegible]	2	89	9	100	[illegible]
2024 Naphtha*	SA	97-117	207-243	3	26	0.74	6.15	[illegible]	127	39	260	21.3	[illegible]	42	52	6	400	[illegible]
2429 Naphtha*	SA	115-143	239-289	10	51	0.76	6.29	[illegible]	125	39	120	22.2	7.8	30	58	12	400	[illegible]
3135 Naphtha*	SA	159-176	318-349	42	108	0.79	6.56	[illegible]	126	39	22	23.7	7.9	35	45	20	200	[illegible]
Varsol® 1 Solvent	BT/SA	160-205	320-401	44	111	0.80	6.67	55	131	39	10	26.6	7.9	46	37	17	100	8052-41-3
Varsol® 18 Solvent	BT/SA	160-205	320-401	43	110	0.79	6.62	62	144	36	10	26.3	7.6	53	40	7	100	8052-41-3
140 Naphtha*	SA	187-209	369-408	65	149	0.80	6.67	58	137	36	6	25.0	7.6	34	46	20	200	[illegible]
DX 3641 Naphtha*	SA	187-210	369-410	64	147	0.79	6.60	67	152	33	6	25.1	7.5	45	49	6	200	[illegible]
AROMATICS																		
Toluene	BT/SA	110-111	230-232	7	45	0.87	7.27	[illegible]	48	105	240	29.5	8.9	-	<0.1	99.9	50	108-88-3
Xylene	BT/SA	139-141	282-286	26	79	0.87	7.26	10[c]	50	98	80	30.0	8.8	-	<0.1	99.9	100	1330-20-7 & 100-41-4
Aromatic 100 Solvent	BT	160-171	320-340	47	117	0.87	7.29	13[c]	55	94	30	30.1	[illegible]	<0.2	-	99.8	50	64742-95-6
Aromatic 150 Solvent	BT	184-204	363-399	66	151	0.90	7.49	15[c]	59	97	6	31.4	[illegible]	<0.2	-	99.8	100	64742-94-5
Aromatic 200 Solvent	BT/SA	231-276	446-530	104[b]	219	1.00	8.34	12[c]	54	98	<1	38.[illegible]	[illegible]	<0.2	-	99.8	100	64742-94-5
DEAROMATIZED ALIPHATICS																		
Exxsol® Isopentane Solvent	KR	N/A	N/A	<-18	<0	0.62	5.21	N/A	N/A	N/A	2,000	14.5	N/A	-	100	<0.01	600	78-78-4
Exxsol® Methylpentane Naphtha	SA	59-62	138-144	-18	<0	0.66	5.50	6	147	28	[illegible]	17.0	7.3	1	99	<0.01	300	64742-49-0
Exxsol® Hexane Solvent	BT/SA	66-69	151-156	-18	0	0.67	5.59	66	151	29	[illegible]	19.4	7.3	8	92	<0.01	50	64742-49-0
Exxsol® D 75/100 Naphtha	SA	76-97	169-207	<-18	<0	0.72	5.99	56	132	36	[illegible]	20.4	[illegible]	19	81	0.01	100	64742-49-0
Exxsol® Heptane Solvent	BT	94-98	201-208	-8	18	0.70	5.79	68	154	29	[illegible]	21.2	[illegible]	4	96	<0.01	400	64742-49-0
Exxsol® D 115/145 Naphtha	SA	116-144	241-291	10	50	0.75	6.22	61	141	35	110	22.1	7.4	41	59	0.01	300	64742-49-0
Exxsol® D 3135 Naphtha	SA	157-177	315-351	41	105	0.77	6.43	66	151	34	24	23.7	7.5	48	52	0.02	300	64742-47-8
Exxsol® D 40 Solvent	BT/SA	159-204	318-399	43	109	0.79	6.49	67	152	34	12	26.0	7.4	57	42	0.4	300	64742-47-8
Exxsol® D 60 Solvent	BT/SA	187-210	369-410	63	146	0.79	6.54	71	159	32	6	25.1	7.4	51	49	0.4	300	64742-47-8
Exxsol® D 80 Solvent	BT	207-234	405-454	82	180	0.80	6.65	76	169	29	<1	27.6	7.4	47	53	<0.2	300	64742-47-8
Exxsol® D 110 Solvent	BT	251-269	483-516	114	238	0.81	6.77	84	183	25	<1	28.6	7.2	41	59	<0.5	300	64742-47-8
Exxsol® D 130 Solvent**	BT	276-316	538-585	137	279	0.81	6.99	89	192	24	<1	29.7	7.2	43	57	<0.5	300	64742-47-8
ISOPARAFFINS																		
Isopar® C Solvent	BT	98-104	208-219	-8	18	0.70	5.83	78	173	27	560	20.3	7.2	-	100	<0.01	400	64741-66-8
Isopar® E Solvent	BT	118-137	244-279	7	45	0.72	6.02	75	167	29	160	22.1	7.3	1	99	<0.01	400	64741-66-8
Isopar® G Solvent	BT	160-176	320-349	41	106	0.75	6.23	[illegible]	181	27	30	23.8	7.3	5	95	<0.01	300	64742-48-9
Isopar® G Naphtha	SA	156-172	313-342	39	103	0.74	3.18	77	171	28	35	22.2	7.3	1	99	0.03	300	64742-48-9
Isopar® H Solvent	BT	178-188	352-370	54	129	0.76	6.32	84	183	26	9	24.1	7.3	5	95	<0.01	300	64742-48-9
Isopar® K Solvent	BT	178-197	351-387	57	135	0.76	6.34	83	181	27	8	24.2	7.3	6	94	<0.01	300	64742-48-9
Isopar® K Naphtha	SA	182-204	360-399	60	140	0.76	6.35	81	178	28	7	23.3	7.3	3	97	<0.01	300	64742-48-9
Isopar® L Solvent	BT	189-207	372-405	64	147	0.77	6.40	85	185	27	4	25.1	7.3	11	89	<0.01	300	64742-48-9
Isopar® M Solvent	BT/SA	223-254	433-489	93[b]	199	0.79	6.57	91	196	25	<1	26.4	7.2	21	80	<0.05	300	64742-47-8
Isopar® V Solvent	BT	273-312	523-594	129[b]	265	0.82	6.82	92	198	23	<1	26.9	7.2	34	66	<0.5	300	64742-46-7
NORMAL PARAFFINS																		
Norpar® 12 Solvent	BT	188-220	370-428	69	156	0.75	6.24	82	180	23	3	26.9	7.3	-	100	<0.01	300	64771-72-8
Norpar® 13 Solvent	BT	222-243	432-469	95[b]	203	0.76	6.35	88	190	21	<1	26.7	7.2	-	100	<0.01	300	64771-72-8
Norpar® 15 Solvent	BT	255-279	491-534	120[b]	248	0.77	6.44	93	199	20	<1	28.9	7.1	-	100	0.01	300	64771-72-8

(a) Tag Closed Cup, ASTM D 56
(b) ASTM D 93
(c) ASTM D 611 (Mixed Aniline Point)

(d) Occupational Exposure Limits - Recommended by Exxon. TLV's have not been established for these compounds by ACGIH.
(e) TLV - A registered trademark of the ACGIH. Threshold Limit Value (TLV) or Occupational Exposure Limit, is the time weighted average concentration for a normal 8-hour workday, 40-hour workweek, to which nearly all workers may be exposed repeatedly with adverse effect.

NOTE:
All hydrocarbon solvents test +30 Saybolt Color except for Aromatic 150 @ +28 & Aromatic 200 @ ASTM 1 by ASTM D 1500.
BT - Baytown SA - Sarnia KR - King Ranch
* Marketed as Isosol® or Varsol® Solvents in Canada
** Preproduction data - Commercially available first quarter 1995

Table 2.131: Fina Aromatic Solvents *(6)*

Typical Properties

Solvent Name	Flash Deg. F	API Gravity	Specific Gravity	Distillation Deg. F	Common Applications
FAS 70	180	20	0.9340	450 - 645	Warmer climate oil well applications Wood treating preservative
FAS 104	115	30	0.8762	300 - 495	Down hole oil well applications Wash oil Reaction solvent in chemical processing Carrier solvent for specialty chemicals High octane gasoline blendstock
FAS 150	155	22	0.9218	370 - 630	Very similar to FAS 104 except higher flash. Used in the same applications as FAS 104.
FAS TX-150	155	26	0.8984	360 - 400	Water white (Saybolt +30) solvent Paint blendstock/solvent Reaction solvent in chemical processing for specialty paint and oilfield chemicals Oilfield chemical solvent High quality wash oil
FAS TX-200	219	11	0.9930	450 - 527	Carrier for agricultural products High flash solvent applications in coatings Used in manufacturing specialty chemicals
Toluene (90% Purity)		31	0.8708	232 - 253	High octane, low RVP gasoline blendstock
Xylene		31	0.8708	281 - 285	Many uses in solvents, gasoline, chemical processing

Table 2.132: Hoechst Celanese Methyl Isobutyl Ketone *(42)*

Methyl Isobutyl Ketone

(MIBK; Isobutyl methyl ketone; Hexone; Isopropylacetone; 4-Methyl-2-pentanone)

Physical Properties

Autoignition Temperature:	840°F (449°C)
Critical Compressibility Factor:	0.254
Critical Pressure:	32.3 atm
Critical Temperature:	298.3°C
Critical Volume:	0.369 m^3/kmol
Dipole Moment:	9.0 X 10^{-30} cm
Evaporation Rate (n-BuAc = 1):	1.54
Flammability Limit (vol % in air):	
Upper Limit:	8.0
Lower Limit:	1.2
Flash Point (Tag Closed Cup):	60°F (16°C)
Freezing Point:	<-50°C (<-58°F)

Heat of Vaporization:					
(BTU/lb)	182	177	172	167	136
Temperature (°F)	26	61.9	98.1	134	315

Liquid Density: (lb/gal)	6.86	6.71	6.55	6.24	5.90
Temperature (°F)	25.7	61.9	98.1	171	243

Liquid Heat Capacity:				
(BTU/lb/°F)	0.514	0.518	0.521	0.546
Temperature (°F)	77.0	85.7	94.4	155

Liquid Thermal Conductivity:			
(BTU/ft/sec/°F)	2.45 X 10^{-5}	2.32 X 10^{-5}	2.06 X 10^{-5}
Temperature (°F)	5.03	54.7	154

Liquid Viscosity: (cp)	0.774	0.570	0.436	0.345
Temperature (°F)	32.8	70.7	109	147

Normal Boiling Point (760 mm Hg):	116°C (241°F)
Solubility (grams/100 grams of water at 20°C):	1.95
Specific Gravity (20°C/4°C):	0.801

Surface Tension: (dynes/cm)	24.4	22.3	16.3
Temperature (°F)	61.9	98.1	207

Vapor Density (Air = 1, at 20°C):	3.46

Vapor Pressure: (mm Hg)	3.15	12.1	14.9	37.1	42.3
Temperature (°F)	25.7	61.9	68.0	98.1	207

Table 2.133: Kendall/Amalie, Witco Special Solvents *(65)*

KENSOL 8

C.A.S. #68410-98-0

ASTM METHOD	PROPERTIES	SPECIFICATION	
D-287*	GRAVITY, API	69.0 MIN	76.0 MAX
D-56	FLASH POINT, (T.C.C.)	-4°F / -20°C MAX	

ASTM METHOD	PROPERTIES	TYPICAL VALUE	
D-287*	GRAVITY, API	72.0	
	LBS./GAL.	5.79	
D-156	COLOR, SAYBOLT	+30	
	ODOR	TYPICAL SOLVENT	
	DOCTOR TEST	SWEET	
D-86*	DISTILLATION,	°F	°C
	IBP	109	43
	5%	129	54
	50%	167	75
	95%	209	98
	EBP	247	119
D-323	REID VAPOR PRESSURE	6.52 LBS/IN^2	
	TOTAL AROMATICS	2.85%	
	BENZENE	1.15%	
	TOLUENE	1.70%	

KENSOL 10

C.A.S. 68410-97-9

ASTM METHOD	PROPERTIES	SPECIFICATION			
D-287*	GRAVITY, API	65 MIN			
D-323	REID VAPOR PRESSURE	4.0 MIN / 6.3 MAX			
D-97	POUR POINT	-40°F / -40°C MAX			
D-86*	DISTILLATION °F	MIN		MAX	
		°F	°C	°F	°C
	IBP	100	38	134	57
	10%	135	57	170	77
	50%	200	93	235	113
	90%	275	135	310	154
	EBP	315	157	350	177

ASTM METHOD	PROPERTIES	TYPICAL VALUE
D-287*	GRAVITY, API	68
	LBS./GAL.	5.9
D-323	REID VAPOR PRESSURE	4.6
D-156	COLOR, SAYBOLT (BEFORE DYE)	+30
D-56	FLASH POINT, (T.C.C.)	-10°F/-23°C

(continued)

Table 2.133: (continued)

KENSOL 17

C.A.S. 64742-48-9

ASTM METHOD	PROPERTIES	SPECIFICATION	
D-287*	GRAVITY, API	58 MIN / 61 MAX	
D-86*	DISTILLATION, °F		
	IBP	170°F MIN	
	EBP	400°F MAX	
		TYPICAL VALUE	
D-287*	GRAVITY, API	61	
	LBS./GAL.	6.12	
D-86*	DISTILLATION	°F	°C
	IBP	175	79
	5%	210	99
	10%	217	103
	50%	244	118
	90%	291	144
	95%	303	151
	EBP	358	181
D-1319	FLORESCENT INDICATOR ANALYSIS (F.I.A.)		
	AROMATICS, VOLUME %	6.5%	
	OLEFINS, VOLUME %	.5%	
	SATURATES VOLUME %	93	
D-156	COLOR, SAYBOLT	+30	
D-56	FLASH POINT, (T.C.C.)	+25°F / -4°C	

KENSOL 30

REGULAR MINERAL SPIRITS, C.A.S. 8052-41-3

ASTM METHOD	PROPERTIES	SPECIFICATION	
D-287*	GRAVITY, API	50.8 MIN / 52.7 MAX	
D-56	FLASH POINT, (T.C.C.)	105°F / 40°C MIN	
D-86*	DISTILLATION, °F		
	5%	310°F MIN	
	95%	390°F MAX	
	EBP	410°F MAX	
		TYPICAL VALUE	
D-287*	GRAVITY, API	52	
	LBS./GAL.	6.42	
D-156	COLOR, SAYBOLT	+30	
	ODOR	MILD PETROLEUM SOLVENT	
D-611	ANILINE POINT	149°F / 65°C	
D-1133	KAURI BUTANOL VALUE	32.5	
D-97	POUR POINT	-40°F / -40°C	
D-1319	FLORESCENT INDICATOR ANALYSIS		
	AROMATICS, VOLUME %	9.4	
	OLEFINS, VOLUME %	.7	
	SATURATES, VOLUME	89.9	
D-86	DISTILLATION	°F	°C
	IBP	306	152
	5%	322	162
	50%	341	170
	95%	375	190
	EBP	393	201

(continued)

Table 2.133: (continued)

KENSOL 33

RULE 66 MINERAL SPIRITS, C.A.S. 8052-41-3

ASTM METHOD	PROPERTIES	SPECIFICATION	
D-287*	GRAVITY, API	51 MIN / 54 MAX	
D-56	FLASH POINT, (T.C.C.)	105°F / 40°C MIN	
D-86*	DISTILLATION, °F		
	5%	310°F MIN	
	95%	390°F MAX	
	EBP	410°F MAX	
	UV ANALYSIS, VOL % AROMATICS	7.2 MIN / 7.8 MAX	
		TYPICAL VALUE	
D-287*	GRAVITY, API	52	
	LBS./GAL.	6.42	
D-156	COLOR, SAYBOLT	+30	
D-611	ANILINE POINT	65	
D-1133	KAURI BUTANOL VALUE	32.5	
D-97	POUR POINT	-40°F / -40°C	
D-1319	FLORESCENT INDICATOR ANALYSIS		
	AROMATICS, VOLUME %	7.5	
	OLEFINS, VOLUME %	0.5	
	SATURATES, VOLUME	92	
D-86	DISTILLATION	°F	°C
	IBP	318	137
	5%	325	161
	50%	339	169
	95%	368	185
	EBP	391	197

KENSOL 48T

NARROW CUT PETROLEUM DISTILLATE, C.A.S. #64741-86-2

ASTM METHOD	PROPERTIES	SPECIFICATION	
D-92	FLASH POINT °F, COC	170 / 77°C MIN	
D-287*	GRAVITY, °API	46.8 MIN - 48.0 MAX	
D-86*	DISTILLATION, °F		
	IBP	380 MIN / 193°C MIN	
	EBP	475 MAX / 246°C MAX	
		TYPICAL VALUE	
D-287*	GRAVITY °API	47.4	
	LBS./GAL.	6.5	
D-92	FLASH POINT °F, COC	185 / 85°C	
D-156	COLOR, SAYBOLT	+30	
D-1611	ANILINE POINT, °C	72.5 / 162°F	
D-1133	KAURI BUTANOL VALUE	28.3	
D-86	DISTILLATION	°F	°C
	IBP	391	199
	10%	409	209
	50%	422	217
	90%	443	228
	EBP	465	241
D-97	POUR POINT, °F	-40 / -40°C	
D-88	VISCOSITY @ 100°F, SUS	31.2	
D-445	VISCOSITY @ 40°C, CST	1.56	
	DOCTOR TEST	SLIGHTLY SOUR	
	COPPER STRIP CORROSION	1b	
D-1319	F.I.A. ANALYSIS, VOLUME %		
	AROMATICS	11.4	
	OLEFINS	3.1	
	SATURATES	85.5	

Table 2.134: Mobil Oil Aliphatic and Aromatic Solvents *(64)*

Toluene, Nitration Grade

Property	Method	Specification	Typical
Acidity	ASTM D 847	No Free Acid	Negative
Acid Wash Color	ASTM D 848	2 max	< 1
Appearance at 65 to 78 °F (18.3 to 25.6 °C)	Visual	Clear Liquid Free of Sediment & Haze	Clear
Color, Platinum-Cobalt	ASTM D 1209	20 max	0
Copper Corrosion	ASTM D 849	Negative	Pass 1A
Distillation Range including 110.6 °C at 760 mm Hg Pressure, °C	ASTM D 850	1 max	0.7
Non-Aromatics, Volume %	Gas Chromatograph	1.5 max	0.02
Specific Gravity, 60/60 °F (15.6/15.6 °C)	ASTM D 891	0.869 - 0.873	0.872
Sulfur Compounds	ASTM D 853	Free of H_2S & SO_2	Negative

Complies with ASTM D 841	Product Number: 871004 (lbs), 868224 (gals)
Pounds per Gallon, 60 °F (15.6 °C): 7.26	Specification Date: August 1, 1996

Solvent Xylene

Property	Method	Specification	Typical
Acidity	ASTM D 847	No Free Acid	Negative
Acid Wash Color	ASTM D 848	6 max	3
Color, Platinum-Cobalt	ASTM D 1209	20 max	0
Copper Corrosion	ASTM D 849	Negative	Pass 1A
Distillation, °C	ASTM D 850		
Initial Boiling Point		137 min	138
Dry Point		143 max	140
Range including 139.3 °C at 760 mm Hg Pressure		5 max	2
Specific Gravity, 60/60 °F (15.6/15.6 °C)	ASTM D 891	0.860 - 0.875	0.871
Sulfur Compounds	ASTM D 853	Free of H_2S & SO_2	Negative

Complies with ASTM D 843	
Pounds per Gallon, 60 °F (15.6 °C): 7.26	Product Number: 870808 (lbs), 868182 (gals)
Production Point: Chalmette, LA	Specification Date: August 1, 1996

(continued)

Table 2.134: (continued)

Pegasol R-100 Aromatic Solvent

Property	Method	Specification	Typical
Appearance	Visual	Report	Clear & Bright
Aromatics, Volume %	Gas Chromatograph	95 min	99.3
Benzene, Volume %	Gas Chromatograph	0.1 max	< 0.01
Distillation, °F	ASTM D 86		
Initial Boiling Point		300 min	310
Dry Point		350 max	340
Flash Point, TCC, °F	ASTM D 56	105 min	109
Kauri-Butanol Value	ASTM D 1133	Report	91
Specific Gravity, 60/60 °F (15.6/15.6 °C)	ASTM D 891	0.865 - 0.885	0.875

Pounds per Gallon, 60 °F (15.6 °C): 7.30	Product Number: 870204 (lbs), 868331 (gals)
Production Point: Chalmette, LA	Specification Date: August 1, 1996

T-400 Aromatic Solvent

Property	Method	Specification	Typical
Appearance	Visual	Report	Clear & Bright
Aromatics, Volume %	Gas Chromatograph	95 min	99.3
Distillation, °F	ASTM D 86		
Initial Boiling Point		300 min	310
Dry Point		400 max	340
Flash Point, TCC, °F	ASTM D 56	105 min	109
Kauri-Butanol Value	ASTM D 1133	Report	91
Specific Gravity, 60/60 °F (15.6/15.6 °C)	ASTM D 891	0.865 - 0.885	0.875

Pounds per Gallon, 60 °F (15.6 °C): 7.30	Product Number: 870915 (lbs), 860916 (gals)
Production Point: Chalmette, LA	Specification Date: August 1, 1996

(continued)

Table 2.134: (continued

T-500-100 Aromatic Solvent

Property	Method	Specification	Typical
Acidity	ASTM D 847	No Free Acid	Negative
Aromatics, Volume %	Gas Chromatograph	94 min	99.4
Copper Corrosion	ASTM D 849	Negative	Pass 1A
Distillation, °F	ASTM D 850		
Initial Boiling Point		290 min	300
Dry Point		345 max	340
Doctor	ASTM D 4952	Sweet	Negative
Flash Point, TCC, °F	ASTM D 56	100 min	102
Kauri-Butanol Value	ASTM D 1133	Report	92
Specific Gravity, 60/60 °F (15.6/15.6 °C)	ASTM D 891	0.860 - 0.875	0.874
Sulfur Compounds	ASTM D 853	Free of H_2S & SO_2	Negative

Pounds per Gallon, 60 °F (15.6 °C): 7.29	Product Number: 870923 (lbs), 860924 (gals)
Production Point: Chalmette, LA	Specification Date: August 1, 1996

Pegasol R-150 Aromatic Solvent

Property	Method	Specification	Typical
Appearance	Visual	Clear & Bright	Clear & Bright
Aromatics, Volume %	Gas Chromatograph	95 min	99.7
Color, Saybolt	ASTM D 156	+ 25 min	30
Distillation, °F	ASTM D 86		
Initial Boiling Point		350 min	360
Dry Point		420 max	380
Flash Point, TCC, °F	ASTM D 56	142 min	145
Kauri-Butanol Value	ASTM D 1133	89 min	90
Specific Gravity, 60/60 °F (15.6/15.6 °C)	ASTM D 891	0.890 - 0.910	0.892

Pounds per Gallon, 60 °F (15.6 °C): 7.50	Product Number: 870212 (lbs), 868323 (gals)
Production Point: Chalmette, LA	Specification Date: August 1, 1996

Table 2.135: Penreco Hydrocarbon Solvents *(18)*

Specifications	2251 Oil	2263 Oil	2257 Oil	2269 Oil	2260 Oil
CAS No.	64742-14-9	64742-47-8	64742-46-7	8042-47-5	8042-47-5
API Gravity, 60°F	46/50	46/50	44/47	43/47	40/44
Specific Gravity, 60/60°F	.779/.797	.779/.797	.793/.806	.793/.811	.806/.825
Distillation, ASTM D 86 IBP, °F, min (°C, min)	375 (191)	375 (191	430 (221)	445 (235)	510 (266)
End Point, °F, max (°C, max)	460 (238)	460 (238	500 (260)	540 (282)	595 (313
Physical Properties (Typical)					
Specific Gravity, 60/60°F	.786	.786	.795	.804	.812
Pounds/Gallon, 60°F	6.56	6.56	6.64	6.69	6.76
Viscosity, 100°F, SUS	32.0	32.0	33.2	34.5	38.0
Viscosity, 100°F, CST	1.66	1.68	2.18	2.28	4.30
Aniline Point, ASTM D 611, °F	170	168	175	181	192
KB Values, ASTM D 1133	28	29	26.5	24.5	22.6
Flash Point, ASTM D 92, °F (°C)	165 (74)	165 (74)	210 (99)	215 (102)	260 (127)
Pour Point, ASTM D 97, °F (°C)	-40 (-40)	-40 (-40)	-15 (-26)	0 (-18)	25 (-4)
Chemical Properties (Typical)					
Aromatics by UV, Wt%	<1	<1	<1	<1	<1
Carbon Number, by GC	C_{10}-C_{14}	C_{10}-C_{14}	C_{11}-C_{16}	C_{12}-C[illegible]	C_{13}-C_{18}

Table 2.136: Phillips 66 High Purity Hydrocarbon *(4)*

HYDROCARBON LIQUIDS

PRODUCT GRADE	CATALOG NO.	MINIMUM PURITY MOL %
n-Butylbenzene		
Pure	A63400	99.0
Isobutylbenzene		
Pure	A65400	99.0
Cyclohexane		
Pure	N24400	99.0
98%	N24900	98.0
Cyclopentane		
Pure	N22400	99.0
70%	N22800	—
n-Decane		
Pure	P10400	—
2, 2-Dimethylbutane, (Neohexane)		
Pure	I34400	99.0
3, 3-Dimethylbutene-1 (Neohexene)	O20300	95.0
n-Dodecane		
Technical	P12300	95.0
n-Heptane		
Pure	P07400	99.0
Commercial	P07200	—
ASTM	P07444	—
n-Hexane		
Pure	P06400	99.0
Technical	P06300	95.0
High Purity	P06200	85.0
Hexene-1		
Technical	O21300	95.0
Isohexanes		
Commercial	I36200	—

HYDROCARBON LIQUIDS

PRODUCT GRADE	CATALOG NO.	MINIMUM PURITY MOL %
Isopentane		
Pure	I26400	99.0
Commercial	I26200	—
2-Methylbutene-2		
Commercial	O17800	—
Methylcyclohexane		
Pure	N29400	—
2-Methylpentane		
Pure	I30400	99.0
3-Methylpentane		
Pure	I32400	99.0
n-Octane		
Technical	P08700	97.0
n-Pentane		
Pure	P05400	99.0
Commercial	P05392	98.0
Toluene		
Pure	A42400	99.0
Reference Fuel	A42444	—
2,2,4-Trimethylpentane (see Isooctane)		
ortho-Xylene		
Pure	A47400	99.0
Technical	A47300	95.0
meta-Xylene		
Technical	A44300	95.0
para-Xylene		
Pure	A48400	99.0

Table 2.137: Shell Chemical Solvents *(14)*

OXYGENATED SOLVENTS

		Molecular Weight	Boiling Point (or Range) °C	Boiling Point (or Range) °F	Freezing Point, °C[1]	Flash Point °F ± 5° (Tag Closed Cup)	Vapor Pressure mmHg @ 20°C[1]	Refractive Index n 20[1] D	Surface Tension, Dynes/CM 20°C[1]	Coefficient of Expansion @ 20°C $\left(\frac{\Delta V}{V \Delta T}\right)$	Average Pounds Per Gallon @ (VOC Content) 25°C	Average Pounds Per Gallon @ (VOC Content) 60°F	Average Specific Gravity 25/25°C	Average Specific Gravity 60/60°F
Fast Evaporating—Relative Evaporation Rate)3.0														
ACETONE[6]	CH_3COCH_3	58.08	56.1	133.0	- 94.9	–15	185.46	1.3590	22.32	0.00143	6.55	6.64	0.788	0.797
ETHYL ACETATE (85-88%)[7]	$CH_3COOC_2H_5$	88.10	70-85	158-185	—	24	—	—	—	0.00134	7.33	7.42	0.881	0.890
ETHYL ACETATE (95-98%)	$CH_3COOC_2H_5$	88.10	73-80	163-176	—	—	—	—	—	0.00134	7.43	7.51	0.894	0.902
ETHYL ACETATE (99%)	$CH_3COOC_2H_5$	88.10	77.1	170.8	- 83.6	—	73.8	1.3725	23.9	0.00134	7.46	7.55	0.897	0.906
METHYL ACETATE (80%)	CH_3COOCH_3	74.08	57.1	134.8	- 98.1	14	172.3	1.3594	—	—	7.48	7.58	0.900	0.910
METHYL ETHYL KETONE	$CH_3COC_2H_5$	72.11	79.64	175.35	- 86.69	23	70.92	1.3788	24.6	0.00131	6.67	6.75	0.802	0.812
iso-PROPYL ACETATE (95-97%)	$CH_3COOCH(CH_3)_2$	102.13	88.7	191.7	- 73.1	40	46.9	1.3770	21.2	0.00131	7.19	7.28	0.866	0.875
iso-PROPYL ETHER	$(CH_3)_2CHOCH(CH_3)_2$	102.18	68.5	155.3	- 85.5	–18	119.5	1.3682	17.3	0.0015	5.99	6.07	0.720	0.729
TETRAHYDROFURAN	$OCH_2CH_2CH_2CH_2$	72.10	66.0	150.8	- 108.5	6	130.0	1.4073	26.4[9]	—	7.35	7.42	0.884	0.891
Medium Evaporating—Relative Evaporation Rate 0.8-3.0														
iso-BUTYL ACETATE (90%)	$CH_3COOCH_2CH(CH_3)_2$	116.16	117.2	243.0	- 99.85	68	15.0	1.3880	23.3	0.00119	7.19	7.26	0.865	0.872
n-BUTYL ACETATE (90-92%)	$CH_3COOC_4H_9$	116.16	118-128	244-262	- 73.5	80	8.9	1.3951	24.0	0.00117	7.25	7.32	0.872	0.879
n-BUTYL ACETATE (99%)	$CH_3COOC_4H_9$	116.16	126.1	259.0	—	82	8.5	—	27.6	0.00121	7.30	7.37	0.878	0.885
sec-BUTYL ACETATE (90%)	$CH_3COOCH(CH_3)C_2H_5$	116.16	112.2	234.0	- 98.9	88	16.2	1.3915	22.8	0.00118	7.15	7.23	0.860	0.868
sec-BUTYL ALCOHOL	$CH_3CH_2CHOHCH_3$	74.12	99.5	211.1	- 114.7	72	11.4	1.3969	23.0	0.00101	6.69	6.75	0.805	0.811
tert-BUTYL ALCOHOL	$C(CH_3)_3OH$	74.12	82.6	180.7	25.66	52	29.6[9]	1.3841[10]	20.7	0.00133	6.50	—	0.782[11]	—
1,1,1,-TRICHLOROETHANE	CH_3CCL_3	133.0	165.2	74.0	- .38	none	100.00	1.438	25.6	—	10.91	—	1.319	1.321
DIETHYL KETONE	$C_2H_5COC_2H_5$	86.13	101.5	214.7	- 42.0	55[13]	26.9	1.3905	—	—	6.76	6.82	0.814	0.819
ETHYL ALCOHOL 200 PRF. ANHYD	C_2H_5OH	46.07	78.32	173.0	- 114.1	56	43.9	1.36143	22.27	0.0011	6.53	6.60	0.786	0.793
ETHYL ALCOHOL 190 PRF. (95%)	C_2H_5OH	46.07	—	—	—	61	—	—	—	0.0011	6.73	6.79	0.809	0.816
METHYL ALCOHOL	CH_3OH	32.04	64.5	148.1	- 97.8	51	97.5	1.329	22.6	0.00119	6.56	6.63	0.789	0.796
METHYL ISOBUTYL KETONE	$CH_3COCH_2CH(CH_3)_2$	100.16	116.2	241.2	- 83.5	60	14.5	1.3957	23.64	0.00115	6.64	6.71	0.799	0.806
METHYL ISOPROPYL KETONE	$CH_3COCH(CH_3)_2$	86.13	93.9	201.0	- 92.0	—	39.8	1.3862	—	0.001	6.65	6.71	0.801	0.806
METHYL n-PROPYL KETONE	$CH_3COC_3H_7$	86.13	102.3	216.1	- 77.5	45	27.0	1.3902	26.6[9]	0.0012	6.69	6.75	0.805	0.810
2-NITROPROPANE	$CH_3CHNO_3CH_3$	89.09	120.3	248.5	- 93.0	82	12.9	1.3941	30.0	0.00104	8.20	8.26	0.987	0.992
n-PROPYL ACETATE (90-92%)	$CH_3COOC_3H_7$	102.13	101.6	214.9	- 92.5	58	24.8	1.3844	23.9	0.00126	7.29	7.37	0.877	0.885
iso-PROPYL ALCOHOL	$(CH_3)_2CHOH$	60.09	82.33	180.2	- 88.43	53	32.0	1.3772	21.35	0.00104	6.51	6.57	0.783	0.790
n-PROPYL ALCOHOL	C_3H_7OH	60.09	97.15	206.9	- 127.0	77	14.2	1.385	23.8	0.00096	6.67	6.74	0.803	0.809

(continued)

Table 2.137: (continued)

		Evaporation Characteristics		Viscosities cps @ 25°C		Blush Resist % Rel. Hum. @ 80°F[3]	Dilution Ratio[4]		Solubility of Pure Compound @ 20°C, % by Weight		Physical Chemical Parameters		Hydrogen Bonding	
		Seconds to 90% Evap.[2]	Relative Rate nBuOAc =1.0	Neat Compound	8gm N.C.[3] Solution		Toluene	Aliphatic Naphtha[5]	In Water	Water In	Solubility Parameter	Fractional Polarity	Index	Characteristics
Fast Evaporating—Relative Evaporation Rate 〉3.0														
ACETONE[6]	CH_3COCH_3	82	5.59	0.31	10	<20	4.4	0.8	Complete		10.0	0.623	12.5	Acceptor
ETHYL ACETATE (85-88%)[7]	$CH_3COOC_2H_5$	115	3.98	0.47	18	37	3.3	1.3	7.9	3.3	9.6	0.171	4.9	Acceptor
ETHYL ACETATE (95-98%)	$CH_3COOC_2H_5$	117	3.91	0.46	19	44	3.1	1.1	8.7	3.3	9.3	0.156	—	Acceptor
ETHYL ACETATE (99%)	$CH_3COOC_2H_5$	117	3.91	0.45	20	—	3.1	1.1	2.9	3.0	9.1	0.151	8.9	Acceptor
METHYL ACETATE (80%)	CH_3COOCH_3	93	4.92	0.42	16	<35	2.9	0.9	24.5	8.2	10.5	0.101	—	Acceptor
METHYL ETHYL KETONE	$CH_3COC_2H_5$	121	3.79	0.41	15	36	4.3	0.9	27.1	12.5	9.3	0.514	10.5	Acceptor
iso-PROPYL ACETATE (95-97%)	$CH_3COOCH(CH_3)_2$	134	3.42	0.52	27	62	2.8	1.3	2.9	1.9	8.6	0.131	8.5	Acceptor
iso-PROPYL ETHER	$(CH_3)_2CHOCH(CH_3)_2$	57	8.04	0.35	COSOLVENT FOR NITROCELLULOSE				1.1	0.5	7.0	0.021	15.6	D-A[8]
TETRAHYDROFURAN	$OCH_2CH_2CH_2CH_2$	97	4.72	0.50	21	50	2.9	1.1	Complete		9.9	0.135	16.5	Acceptor
Medium Evaporating—Relative Evaporation Rate 0.8-3.0														
iso-BUTYL ACETATE (90%)	$CH_3COOCH_2CH(CH_3)_2$	305	1.50	0.68	37	78	2.2	1.1	0.67	1.65	8.3	0.093	8.7	Acceptor
n-BUTYL ACETATE (90-92%)	$CH_3COOC_4H_9$	458	1.00	0.71	35	82	2.7	1.4	1.0	1.37	9.0	0.096	5.7	Acceptor
n-BUTYL ACETATE (99%)	$CH_3COOC_4H_9$	468	0.98	0.68	44	—	2.7	1.3	—	—	8.6	0.095	10.8	Acceptor
sec-BUTYL ACETATE (90%)	$CH_3COOCH(CH_3)C_2H_5$	257	1.78	0.65	33	76	2.6	1.3	0.74	2.1	8.2	0.090	8.3	Acceptor
sec-BUTYL ALCOHOL	$CH_3CH_2CHOHCH_3$	563	0.81	2.9	COSOLVENT FOR NITROCELLULOSE				15.4	65.1	10.8	0.111	−17.5	D-A
tert-BUTYL ALCOHOL	$C(CH_3)_3OH$	(430)	(1.05)	3.35[12]	COSOLVENT FOR NITROCELLULOSE				Complete		10.2	0.116	−17.0	D-A
1,1,1,-TRICHLOROETHANE	CH_3CCL_3	76	6.0	0.79	—	—	—	—	—	—	8.7	0.0	4.2	Acceptor
DIETHYL KETONE	$C_2H_5COC_2H_5$	205	2.23	0.47	20	76	3.0	0.7	3.4	2.6	9.9	0.403	7.7	Acceptor
ETHYL ALCOHOL 200 PRF. ANHYD	C_2H_5OH	278	1.60	1.1	COSOLVENT FOR NITROCELLULOSE				Complete		12.7	0.299	−17.7	D-A
ETHYL ALCOHOL 190 PRF. (95%)	C_2H_5OH	328	1.40	1.4	COSOLVENT FOR NITROCELLULOSE				Complete		13.2	0.326	—	D-A
METHYL ALCOHOL	CH_3OH	221	2.07	0.56	19	—	2.2	0.5	Complete		14.5	0.484	−19.8	D-A
METHYL ISOBUTYL KETONE	$CH_3COCH_2CH(CH_3)_2$	295	1.61	0.55	19	78	3.6	1.0	2.04	2.41	8.4	0.317	10.5	Acceptor
METHYL ISOPROPYL KETONE	$CH_3COCH(CH_3)_2$	164	2.79	0.48	19	—	3.8	0.9	2.3	2.0	8.9	0.437	10.5	Acceptor
METHYL n-PROPYL KETONE	$CH_3COC_3H_7$	201	2.28	0.68	20	70	4.0	1.1	4.3	3.3	8.7	0.415	11.0	Acceptor
2-NITROPROPANE	$CH_3CHNO_2CH_3$	415	1.10	0.75	63	82	1.2	0.4	1.7	0.6	9.9	0.627	4.0	D-A
n-PROPYL ACETATE (90-92%)	$CH_3COOC_3H_7$	220	2.08	0.59	26	65	3.2	1.5	2.3	2.6	8.75	0.102	8.5	Acceptor
iso-PROPYL ALCOHOL	$(CH_3)_2CHOH$	319	1.44	2.4	COSOLVENT FOR NITROCELLULOSE				Complete		11.5	0.170	−16.7	D-A
n-PROPYL ALCOHOL	C_3H_7OH	530	0.86	2.0	COSOLVENT FOR NITROCELLULOSE				Complete		11.9	0.199	−16.5	D-A

(continued)

Table 2.137: (continued)

		Molecular Weight	Boiling Point (or Range) °C	°F	Freezing Point, °C[1]	Flash Point °F ± 5° (Tag Closed Cup)	Vapor Pressure mmHg @ 20°C[1]	Refractive Index n 20[1] D	Surface Tension, Dynes/CM 20°C[1]	Coefficient of Expansion @ 20°C $\left(\frac{\Delta V}{V \Delta T}\right)$	Average Pounds Per Gallon @ (VOC Content) 25°C	60°F	Average Specific Gravity 25/25°C	60/60°F
Slow Evaporating—Relative Evaporation Rate ⟨0.8														
AMYL ACETATE (ex Fusel Oil) (85-88%)	$CH_3COOC_5H_{11}$	130.18	146.0	294.8	- 100.0	93[13]	5.2	1.401	24.3	0.00104	7.14	7.21	0.859	0.866
AMYL ACETATE, PRIMARY (Mixed Isomers) (95%)	$CH_3COOC_5H_{11}$	130.18	146.0	294.8	- 100[15]	101	3.8	1.4013	28.5	0.00115	7.26	7.34	0.874	0.881
AMYL ALCOHOL, PRIMARY (Mixed Isomers)	$C_5H_{11}OH$	88.15	133.1	271.6	- 90.0	—	2.9	1.4014	23.8	0.00092	6.77	6.83	0.814	0.820
tert-AMYL ALCOHOL	$(CH_3)_2COHC_2H_5$	88.15	102.2	216.0	- 8.4	—	—	1.4048	—	0.00133	5.71	6.77	0.807	0.814
iso-BUTYL ALCOHOL	$CH_3CH(CH_3)CH_2OH$	74.12	107.8	226.0	- 108.0	86	8.8	1.3859	22.8	0.00096	6.65	6.71	0.801	0.806
n-BUTYL ALCOHOL	C_4H_9OH	74.12	117.7	243.9	- 89.0	98	4.1	1.3993	24.6	0.00090	6.72	6.78	0.808	0.814
BUTYL DIOXITOL® GLYCOL ETHER	$C_4H_9O(C_2H_4O)_2H$	162.22	230.4	446.7	- 68.1	220	<0.01	1.4316	30.0[9]	0.00085	7.95	8.01	0.956	0.962
BUTYL OXITOL® GLYCOL ETHER	$C_4H_9OC_2H_4OH$	118.17	171.2	340.2	- 75.0	143	0.8	1.4193	27.3	0.00092	7.49	7.55	0.901	0.907
m-CRESOL	$CH_3C_6H_4OH$	108.141	202.0	396.0	- 12.2	187[16]	0.14[9]	1.5414	38.01[17]	—	8.58	—	1.030	—
CYCLOHEXANOL	$CH_2CH_2CH_2CH_2CH_2CHOH$	100.16	160.65	321.2	- 25.15	154	1.1	1.4656	35.1	0.00077	7.87	7.94	0.947	0.953
CYCLOHEXANONE	$CH_2CH_2CH_2CH_2CH_2CO$	98.14	156.7	314.1	- 47.0	111	3.4	1.4507	27.7	0.00094	7.86	7.93	0.946	0.952
DIACETONE ALCOHOL	$(CH_3)_2C(OH)CH_2COCH_3$	116.16	169.2	362.8	- 44.0	133	0.95	1.4234	28.9	0.00094	7.79	7.86	0.937	0.944
DIBASIC ESTER	$CH_3OCO(CH_2)_nCOOCH_{3\,(n=2\ to\ 4)}$	159.0	196-225	385-437	- 20.0	212	0.24	1.4213	35.1	0.0010	9.13	9.23	1.097	1.1075
DIETHYLENE GLYCOL	$HO(C_2H_4O)_2H$	106.12	245.0	473.0	- 7.8	300[20]	0.02	1.4472	48.5	0.000635	9.28	9.33	1.116	1.120
DIETHYLENE GLYCOL MONOBUTYL ETHER ACETATE (95%)	$CH_3COO(C_2H_4O)_2C_4H_9$	204.27	246.0	475.0	- 32.2	240[13]	<0.01	1.4262	—	0.00101	8.15	8.19	0.981	0.984
DIISOBUTYL KETONE	$(CH_3)CHCH_2COCH_2CH(CH_3)_2$	142.23	169.3	336.7	- 41.5	140	1.4	1.4230	22.5	0.00102	6.70	6.76	0.806	0.811
DIMETHYL FORMAMIDE	$CHON(CH_3)_2$	73.09	153.0	307.4	- 61.0	135	2.7	1.4269[9]	35.2	—	7.79	7.87	0.938	0.945
DIETHYLENE GLYCOL MONOETHYL ETHER–low gravity	$C_2H_5O(C_2H_4O)_2H$	134.18	201.9	395.4	- 76.0	192	0.2	1.4273	35.5	0.00090	8.21	8.28	0.988	0.994
DIETHYLENE GLYCOL MONOETHYL ETHER–high gravity	$C_2H_5O(C_2H_4O)_2H$	—	190-205	374-401	—	201	0.1	1.4286	—	0.00090	8.51	8.58	1.024	1.030
DIPROPYLENE GLYCOL MONOMETHYL ETHER	$CH_3OCH_2CHCH_3OCH_2CHCH_3OH$	148.2	188.3	371.0	- 80.0	167	0.4	1.4198	28.8	0.00091	7.91	7.98	0.951	0.957
DIPROPYLENE GLYCOL MONOMETHYL ETHER ACETATE	$CH_3OCH_2CHCH_3OCH_2CHCH_3OOCCH_3$	190.2	205.0	401.0	—	187	0.2	1.4140	28.3	—	8.09	8.18	0.972	0.983
ETHYL BUTYL KETONE	$C_2H_5COC_4H_9$	114.18	147.6	297.7	- 39.0	115[13]	10.2	1.4085	—	0.00106	6.79	6.85	0.816	0.822

(continued)

Table 2.137: (continued)

		Evaporation Characteristics		Viscosities cps @ 25°C		Blush Resist	Dilution Ratio[4]		Solubility of Pure Compound @ 20°C, % by Weight		Physical Chemical Parameters		Hydrogen Bonding	
		Seconds to 90% Evap.[2]	Relative Rate nBuOAc =1.0	Neat Compound	8gm N.C.[3] Solution	% Rel. Hum. @ 80°F[3]	Toluene	Aliphatic Naphtha[5]	In Water	Water In	Solubility Parameter	Fractional Polarity	Index	Characteristics
Slow Evaporating—Relative Evaporation Rate <0.8														
AMYL ACETATE (ex Fusel Oil) (85-88%)	$CH_3COOC_5H_{11}$	689	0.67	0.83	39	88	2.5	1.7	0.17	1.15	8.9	0.068	8.2	Acceptor
AMYL ACETATE, PRIMARY (Mixed Isomers) (95%)	$CH_3COOC_5H_{11}$	1203	0.38	0.83	55	92	2.3	1.4	0.20	0.90	8.45	0.077	8.2	Acceptor
AMYL ALCOHOL, PRIMARY (Mixed Isomers)	$C_5H_{11}OH$	2305	0.20	3.7	COSOLVENT FOR NITROCELLULOSE				1.7	9.2	10.9	0.074	—	D-A
tert-AMYL ALCOHOL	$(CH_3)_2COHC_2H_5$	505	0.91	3.5	COSOLVENT FOR NITROCELLULOSE				13.7	20.9	10.0	0.093	—	D-A
iso-BUTYL ALCOHOL	$CH_3CH(CH_3)CH_2OH$	740	0.62	1.8	COSOLVENT FOR NITROCELLULOSE				8.7	15.0	10.7	0.125	−17.9	D-A
n-BUTYL ALCOHOL	C_4H_9OH	1076	0.43	2.6	COSOLVENT FOR NITROCELLULOSE				7.7	20.1	11.4	0.102	−18.0	D-A
BUTYL DIOXITOL® GLYCOL ETHER	$C_4H_9O(C_2H_4O)_2H$	150390	<0.01	5.3	215	85	3.9	1.9	Complete		8.9	0.060	0.0	D-A
BUTYL OXITOL® GLYCOL ETHER	$C_4H_9OC_2H_4OH$	6750	0.07	2.9	107	96	3.3	1.8	Complete		8.9	0.128	0.0	D-A
m-CRESOL	$CH_3C_6H_4OH$	—	<0.1	9.8[12]	—	—	—	—	2.51[18]	—	11.7	0.047	−15.0	D-A
CYCLOHEXANOL	$CH_2CH_2CH_2CH_2CH_2CHOH$	9160	0.05	52.7	COSOLVENT FOR NITROCELLULOSE				0.13	11.8	11.4	0.082	−14.8	D-A
CYCLOHEXANONE	$CH_2CH_2CH_2CH_2CH_2CO$	1566	0.29	2.0	74	92	5.8	1.3	2.3	8.0	9.9	0.469	13.7	Acceptor
DIACETONE ALCOHOL	$(CH_3)_2C(OH)CH_2COCH_3$	3840	0.12	2.9	137	82[19]	2.3	0.6	Complete		9.2	0.459	0.0	D-A
DIBASIC ESTER	$CH_3OCO(CH_2)_nCOOCH_{3\,(n=2\ to\ 4)}$	56700	<0.01	2.39	—	—	—	—	5.3	3.1	9.7	0.140	8.2	Acceptor
DIETHYLENE GLYCOL	$HO(C_2H_4O)_2H$	—	<0.001	28.9	—	—	—	—	Complete		12.1	0.602	0.0	D-A
DIETHYLENE GLYCOL MONOBUTYL ETHER ACETATE (95%)	$CH_3COO(C_2H_4O)_2C_4H_9$	327780	<0.01	3.1	—	—	1.8	0.9	6.5	3.7	8.8	0.093	—	Acceptor
DIISOBUTYL KETONE	$(CH_3)CHCH_2COCH_2CH(CH_3)_2$	2437	0.19	0.95	126	95	1.5	0.8	<0.05	0.75	7.8	0.157	9.8	Acceptor
DIMETHYL FORMAMIDE	$CHON(CH_3)_2$	2280	0.20	0.82	14	—	7.7	0.2	Complete		12.1	0.796	18.9	D-A
DIETHYLENE GLYCOL MONOETHYL ETHER–low gravity	$C_2H_5O(C_2H_4O)_2H$	27800	0.02	4.0	135	<50[19]	4.8	Imm.	Complete		9.7	0.092	0.0	D-A
DIETHYLENE GLYCOL MONOETHYL ETHER–high gravity	$C_2H_5O(C_2H_4O)_2H$	36300	0.01	7.0	320	—	2.0	Imm.	Complete		11.0	0.045	3.4	D-A
DIPROPYLENE GLYCOL MONOMETHYL ETHER	$CH_3OCH_2CHCH_3OCH_2CHCH_3OH$	22900	0.02	3.4	—	—	4.4	0.8	Complete		9.6	0.175	0.0	D-A
DIPROPYLENE GLYCOL MONOMETHYL ETHER ACETATE	$CH_3OCH_2CHCH_3OCH_2CHCH_3OOCCH_3$	42200	<0.01	2.1	—	—	—	—	12.3	—	8.2	0.107	—	Acceptor
ETHYL BUTYL KETONE	$C_2H_5COC_4H_9$	1075	0.43	0.70	49	94	2.6	0.8	1.43	0.78	8.4	0.361	10.0	Acceptor

(continued)

Table 2.137: (continued)

Slow Evaporating—Relative Evaporation Rate ⟨0.8

		Molecular Weight	Boiling Point (or Range) °C	°F	Freezing Point, °C[1]	Flash Point °F ± 5° (Tag Closed Cup)	Vapor Pressure mmHg @ 20°C[1]	Refractive Index n 20[1] D	Surface Tension, Dynes/CM 20°C[1]	Coefficient of Expansion @ 20°C $\left(\frac{\Delta V}{V\Delta T}\right)$	Average Pounds Per Gallon @ (VOC Content) 25°C	60°F	Average Specific Gravity 25/25°C	60/60°F
ETHYL 3-ETHOXY PROPIONATE	$C_2H_5OCOC_2H_4OC_2H_5$	146.2	165-172	329-342	<- 50.0	136	1.11	1.4050	24.2	0.001176	7.82	7.95	0.946	0.954
ETHYLENE GLYCOL	HOC_2H_4OH	62.07	197.3	387.1	- 12.7	250[20]	0.06	1.4318	48.4	0.000566	9.26	9.31	1.114	1.118
2 ETHYL HEXANOL	$C_4H_9CH(C_2H_5)CH_2OH$	130.23	184.8	364.6	- 76.0	166	0.09	1.4328	—	0.00088	6.91	6.96	0.831	0.836
2 ETHYL HEXYL ACETATE (95%)	$CH_3COOCH_2CH(C_2H_5)C_4H_9$	172.27	199.0	390.2	- 80.0	160	0.4	1.4103	—	—	7.23	7.30	0.870	0.876
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE (95%)	$CH_3COOC_2H_4OC_2H_5$	132.16	150-160	302-320	—	126	—	—	—	0.00112	8.06	8.15	0.970	0.978
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE (99%)	$CH_3COOC_2H_4OC_2H_5$	132.16	156.3	313.3	- 61.7	126	2.0	1.4030	28.2	0.00112	8.06	8.15	0.970	0.978
ETHYLENE GLYCOL MONOBUTYL ETHER ACETATE	$CH_3COOC_2H_4OC_4H_9$	160.21	191.6	376.9	- 64.6	165	0.25	1.4200	30.3	0.00104	7.79	7.88	0.938	0.946
HEXYLENE GLYCOL	$CH_3CH(OH)CH_2C(OH)(CH_3)_2$	118.17	198.27	388.9	- 50[15]	211[20]	<0.1	1.4276	33.1	0.00072	7.65	7.71	0.921	0.926
ISOBUTYL ISOBUTYRATE	$(CH_3)_2CHCOOCH_2CH(CH_3)_2$	144.21	147.3	297.1	- 81.0	101	3.0	1.3999	—	—	7.07	7.15	0.851	0.859
ISOPHORONE	$\underline{COCH:C(CH_3)CH_2C(CH_3)_2}CH_2$	138.2	215.2	419.4	- 8.1	184	0.3	1.4775	32.3	0.00085	7.64	7.70	0.919	0.925
METHYL n-AMYL KETONE	$CH_3COC_5H_{11}$	114.18	150.5	302.9	- 35.0	102	1.0	1.4110	—	0.00104	6.77	6.83	0.814	0.820
DIETHYLENE GLYCOL MONOMETHYL ETHER	$CH_3O(C_2H_4O)_2H$	120.15	194.2	381.6	- 85.0	189	0.2	1.4263	34.8[9]	0.00088	8.49	8.56	1.021	1.028
METHYL ISOAMYL KETONE	$CH_3COC_2H_4CH(CH_3)_2$	114.18	145.4	293.7	- 74.21	96	4.0	1.4069	28.5	0.00107	6.79	6.85	0.817	0.822
METHYL ISOBUTYL CARBINOL	$CH_3CH(OH)CH_2CH(CH_3)_2$	102.18	131.8	269.2	- 90[15]	103	4.6	1.4110	22.8	0.00103	6.69	6.75	0.805	0.811
ETHYLENE GLYCOL MONOMETHYL ETHER	$CH_3OC_2H_4OH$	76.09	124.5	256.1	- 85.1	102	7.3	1.4021	30.6	0.00095	8.00	8.08	0.963	0.970
N-METHYL-2-PYRROLIDONE	$\underline{CH_2CH_2N(CH_3)COCH_2}$	99.133	202.0	396.0	- 24.4	204[21]	0.32[9]	1.469[9]	40.7[9]	—	8.59	—	1.031	—
ETHYLENE GLYCOL MONOETHYL ETHER	$C_2H_5OC_2H_4OH$	90.12	135.1	275.2	- 100.0	110	4.1	1.4076	27.9	0.00097	7.72	7.79	0.928	0.935
PROPYLENE GLYCOL	$CH_3CH(OH)CH_2OH$	76.10	187.3	369.1	- 60.0[15]	210	0.15	1.431[10]	36.0	0.000695	8.61	8.66	1.036	1.040
PROYLENE GLYCOL MONOMETHYL ETHER	$CH_3OCH_2CHCH_3OH$	90.1	120.1	248.0	- 95.0	90	10.9	1.4011	27.7	0.00099	7.65	7.72	0.919	0.927
PROPYLENE GLYCOL MONOMETHYL ETHER ACETATE	$CH_3OCH_2CH_3CHOOCCH_3$	132.2	141.0	286.0	<- 67.0	117	3.7	1.3995	27.4	0.00096	8.03	8.10	0.964	0.969
PROPYLENE GLYCOL MONO TERTIARY BUTYL ETHER	$(CH_3)_3COCH_2CHCH_3OH$	132.2	151.0	304.0	- 56.0	113	4.7	1.4116	24.2	—	7.26	7.31	0.872	0.878
TRIETHYLENE GLYCOL	$HO(C_2H_4O)_3H$	150.17	287.4	549.3	- 7.2	305[20]	<0.01	1.4559	45.2	0.00171	9.34	9.39	1.123	1.128
WATER	HOH	18.02	100.0	212.0	- 0.0	—	17.535	1.33299	72.75	—	8.31	8.33	1.000	1.000

(continued)

Table 2.137: (continued)

		Evaporation Characteristics		Viscosities cps @ 25°C		Blush Resist	Dilution Ratio[4]		Solubility of Pure Compound @ 20°C, % by Weight		Physical Chemical Parameters		Hydrogen Bonding	
		Seconds to 90% Evap.[2]	Relative Rate nBuOAc =1.0	Neat Compound	8gm N.C.[3] Solution	% Rel. Hum. @ 80°F[3]	Toluene	Aliphatic Naphtha[5]	In Water	Water In	Solubility Parameter	Fractional Polarity	Index	Characteristics
Slow Evaporating—Relative Evaporation Rate 〈0.8														
ETHYL 3-ETHOXY PROPIONATE	$C_2H_5OCOC_2H_4OC_2H_5$	3900	0.12	1.2	—	—	1.8	0.6	2.9	2.9	8.7	0.094	11.5	Acceptor
ETHYLENE GLYCOL	HOC_2H_4OH	—	<0.01	17.4	—	—	—	—	Complete		14.7	0.476	−13.2	D-A
2 ETHYL HEXANOL	$C_4H_9CH(C_2H_5)CH_2OH$	25730	0.02	7.7	COSOLVENT FOR NITROCELLULOSE				0.07	2.6	9.5	0.045	−18.7	D-A
2 ETHYL HEXYL ACETATE (95%)	$CH_3COOCH_2CH(C_2H_5)C_4H_9$	13750	0.03	1.4	140	94	1.3	0.9	0.03	0.55	8.5	0.020	8.8	Acceptor
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE (95%)	$CH_3COOC_2H_4OC_2H_5$	2706	0.17	1.2	57	91	2.5	0.9	22.9	6.5	8.8	0.163	—	Acceptor
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE (99%)	$CH_3COOC_2H_4OC_2H_5$	2533	0.18	1.2	60	—	2.4	0.9	—	—	8.7	0.160	10.1	Acceptor
ETHYLENE GLYCOL MONOBUTYL ETHER ACETATE	$CH_3COOC_2H_4OC_4H_9$	14310	0.03	1.7	102	96	1.8	1.2	1.1	1.6	8.2	0.060	10.3	Acceptor
HEXYLENE GLYCOL	$CH_3CH(OH)CH_2C(OH)(CH_3)_2$	—	<0.01	29.8	—	—	—	—	Complete		9.7	0.599	−12.3	Acceptor
ISOBUTYL ISOBUTYRATE	$(CH_3)_2CHCOOCH_2CH(CH_3)_2$	965	0.47	0.83	87	—	1.3	0.8	<0.1	<0.2	7.7	0.091	8.0	Acceptor
ISOPHORONE	$COCH{:}C(CH_3)CH_2C(CH_3)_2CH_2$	20000	0.02	2.3	97	97	6.2	—	1.2	4.3	9.1	0.521	14.9	Acceptor
METHYL n-AMYL KETONE	$CH_3COC_5H_{11}$	1376	0.33	0.77	42	93	3.9	1.2	0.43	1.5	8.5	0.236	9.0	Acceptor
DIETHYLENE GLYCOL MONOMETHYL ETHER	$CH_3O(C_2H_4O)_2H$	26260	0.02	3.8	122	57[19]	2.3	Imm.	Complete		10.2	0.108	0.0	D-A
METHYL ISOAMYL KETONE	$CH_3COC_2H_4CH(CH_3)_2$	1016	0.45	0.73	40	89	3.8	1.1	0.55	1.4	8.3	0.240	10.9	Acceptor
METHYL ISOBUTYL CARBINOL	$CH_3CH(OH)CH_2CH(CH_3)_2$	1711	0.27	3.8	COSOLVENT FOR NITROCELLULOSE				1.64	6.35	10.0	0.071	−18.7	D-A
ETHYLENE GLYCOL MONOMETHYL ETHER	$CH_3OC_2H_4OH$	884	0.52	1.6	50	45[19]	3.4	0.2	Complete		10.8	0.281	0.0	D-A
N-METHYL-2-PYRROLIDONE	$CH_2CH_2N(CH_3)COCH_2$	—	<0.1	1.7	—	—	—	—	Complete		11.3	0.727	23.0	D-A
ETHYLENE GLYCOL MONOETHYL ETHER	$C_2H_5OC_2H_4OH$	1213	0.38	1.9	59	67[19]	4.9	1.1	Complete		9.9	0.216	0.0	D-A
PROPYLENE GLYCOL	$CH_3CH(OH)CH_2OH$	—	0.01	43.0	—	—	—	—	Complete		12.6	0.773	−10.9	D-A
PROYLENE GLYCOL MONOMETHYL ETHER	$CH_3OCH_2CHCH_3OH$	600	0.76	1.7	—	—	5.2	0.9	Complete		10.2	0.217	0.0	D-A
PROPYLENE GLYCOL MONOMETHYL ETHER ACETATE	$CH_3OCH_2CH_3CHOOCCH_3$	1410	0.32	1.14	60	—	2.5	0.43	18.5	5.6	9.2	0.153	10.7	Acceptor
PROPYLENE GLYCOL MONO TERTIARY BUTYL ETHER	$(CH_3)_3COCH_2CHCH_3OH$	1830	0.25	3.3	—	—	2.3	1.2	14.5	20.1	8.1	0.128	0.0	D-A
TRIETHYLENE GLYCOL	$HO(C_2H_4O)_3H$	—	<0.01	38.2	—	—	—	—	Complete		11.0	0.656	0.0	D-A
WATER	HOH	1376	0.33	0.92	—	—	—	—	—	—	23.4	0.835	−30.0	D-A

(continued)

Table 2.137: (continued)

HYDROCARBON SOLVENTS (Typical Properties*)

Please Note: Shell Sol 71 has changed to Shell Odorless Mineral Spirits (OMS).

	Calculated Average Molecular Weight[14]	Distillation Range °C	Distillation Range °F	Flash Point °F TCC[23] or SFCC[24]	Vapor Pressure mmHg @ 20 °C	Aniline Cloud Pt. °F	Mixed Aniline Cloud Pt. °F	Kauri Butanol Value	Average Pounds Per Gallon @ (VOC Content) 25°C	Average Pounds Per Gallon @ (VOC Content) 60°F[25]	Average Specific Gravity 25/25°C	Average Specific Gravity 60/60°F[25]
Aliphatic Hydrocarbons												
SHELL SOL B HT	88	61-77	142-170	—	140.0	152	—	29	5.53	5.61	0.666	0.675
SHELL TOLU-SOL® A HT SOLVENT	100	90-97	194-206	7	47.8	155	—	29	5.71	5.79	0.688	0.696
SHELL TOLU-SOL W HT SOLVENT	100	98-110	209-230	20	41.4	129	—	36	6.17	6.23	0.741	0.749
SHELL TOLU-SOL 3 SOLVENT	100	91-97	195-207	—	47.2	150	—	30	5.74	5.82	0.691	0.699
SHELL TOLU-SOL 5 SOLVENT	100	91-98	195-209	10	46.8	146	—	30	5.77	5.85	0.695	0.703
SHELL TOLU-SOL 6 W SOLVENT	100	99-108	211-227	20	40.7	113	—	43	6.23	6.29	0.748	0.755
SHELL TOLU-SOL 10 SOLVENT	99	91-105	196-221	—	45.8	133	—	34	5.87	5.95	0.706	0.714
SHELL TOLU-SOL 19 EC SOLVENT	98	91-104	195-220	14	44.0	116	—	39	6.00	6.08	0.722	0.730
SHELL TOLU-SOL 25 SOLVENT	96	92-107	198-225	—	42.7	105	—	42	6.09	6.17	0.733	0.741
SHELL RUBBER SOLVENT	90	64-114	147-238	—	125.3	135	—	34	5.65	5.79	0.680	0.689
SHELL VM&P NAPHTHA HT	118	119-139	247-282	55	9.8	142	—	35	6.19	6.27	0.745	0.753
SHELL VM&P NAPHTHA EC	117	121-134	249-273	57	9.7	128	—	38	6.24	6.31	0.751	0.758
SHELL MINERAL SPIRITS 135	138	164-202	327-395	112	1.1	138	—	37	6.56	6.63	0.789	0.796
SHELL MINERAL SPIRITS 145 EC	131	162-201	323-393	113	1.2	145	—	35	6.44	6.52	0.776	0.783
SHELL MINERAL SPIRITS 150 EC	132	162-200	323-392	109	1.1	151	—	33	6.40	6.47	0.771	0.778
SHELL MINERAL SPIRITS 200 HT	132	162-206	324-402	111	1.1	154	—	32	6.40	6.47	0.770	0.777
SHELL SOL 340 HT	143	159-176	319-349	103	1.4	152	—	32	6.37	6.44	0.766	0.773
SHELL SOL 142 HT	161	190-207	374-405	145	0.4	159	—	30	6.52	6.58	0.784	0.791
SHELL SOL 71	149	179-204	355-400	125	0.5	184	—	26	6.24	6.32	0.752	0.759
Aromatic Hydrocarbons												
SHELL TOLUENE	92	110-111	231-232	43	21.8	—	50	105	7.16	7.25	0.862	0.871
SHELL XYLENE	106	139-142	283-287	79	6.1	—	53	95	7.17	7.25	0.863	0.871
SHELL CYCLO-SOL® 53 AROMATIC SOLVENT	120	160-176	320-349	111	1.6	—	56	92	7.19	7.27	0.866	0.874
SHELL CYCLO-SOL 63 AROMATIC SOLVENT	134	173-208	343-407	128	0.5	—	57	89	7.35	7.43	0.884	0.892

(continued)

Table 2.137: (continued)

	Evaporation Characteristics[22]			Composition, %v						
				Saturates		Aromatics				
	Seconds to 90% Evap.	Relative Rate nBuOAc =1.0	Neat Viscosity cps @ 25°C	Paraffins	Cycloparaffins	Tol & EB[26]	C_8 & Higher (excluding EB)	Benzene	Total	Solubility Parameter
Aliphatic Hydrocarbons										
SHELL SOL B HT	49	9.4	0.37	94.7	5.3	—	—	0.002	<0.01	7.3
SHELL TOLU-SOL® A HT SOLVENT	96	4.8	0.43	91.2	8.8	—	—	<0.001	<0.01	7.2
SHELL TOLU-SOL W HT SOLVENT	121	3.8	0.54	43	57	<0.01	—	<0.001	<0.01	7.6
SHELL TOLU-SOL 3 SOLVENT	97	4.7	0.43	88.4	8.6	3.0	—	<0.001	3.0	7.3
SHELL TOLU-SOL 5 SOLVENT	98	4.7	0.44	86.6	8.4	5.0	—	<0.001	5.0	7.3
SHELL TOLU-SOL 6 W SOLVENT	123	3.7	0.55	26.1	67.9	6.0	—	<0.001	6.0	7.7
SHELL TOLU-SOL 10 SOLVENT	101	4.5	0.45	82.0	8.0	10.0	—	<0.001	10.0	7.4
SHELL TOLU-SOL 19 EC SOLVENT	107	4.3	0.46	73.9	7.1	19.0	—	<0.001	19.0	7.5
SHELL TOLU-SOL 25 SOLVENT	112	4.1	0.47	68.4	6.6	25.0	—	<0.001	25.0	7.6
SHELL RUBBER SOLVENT	55	8.3	0.41	84.6	6.4	9.0	—	<0.004	8.0	7.4
SHELL VM&P NAPHTHA HT	305	1.5	0.68	54.0	46.0	—	—	<0.003	<0.1	7.6
SHELL VM&P NAPHTHA EC	316	1.4	0.68	50.1	42.8	1.5	5.5	<0.003	7.0	7.7
SHELL MINERAL SPIRITS 135	4660	0.10	1.10	41.9	43.1	—	15.0	<0.0001	15.0	7.6
SHELL MINERAL SPIRITS 145 EC	3250	0.14	1.02	44.5	48.4	—	7.1	<0.0001	7.1	7.5
SHELL MINERAL SPIRITS 150 EC	3415	0.13	1.13	46.5	50.4	—	3.1	<0.0001	3.1	7.5
SHELL MINERAL SPIRITS 200 HT	3420	0.13	1.12	47.9	52.0	—	<0.1	<0.0001	<0.1	7.4
SHELL SOL 340 HT	1725	0.27	0.95	46.0	53.9	—	—	<0.0001	<0.1	7.4
SHELL SOL 142 HT	9250	<0.1	1.44	53.0	47.0	—	—	<0.0001	<0.2	7.4
SHELL SOL 71	5140	<0.1	1.50	—	—	—	—	<0.0001	<0.1	7.4
Aromatic Hydrocarbons										
SHELL TOLUENE	226	2.0	0.62	—	—	—	—	0.005	99.97	8.9
SHELL XYLENE	628	0.73	0.87	—	—	19.0	80.5	<0.0005	99.5	8.8
SHELL CYCLO-SOL® 53 AROMATIC SOLVENT	2215	0.21	0.88	—	—	—	99.4	<0.0001	99.4	8.8
SHELL CYCLO-SOL 63 AROMATIC SOLVENT	5000	<0.1	1.08	—	—	—	97.5	<0.0001	97.5	8.8

NOTES

***Typical properties are to be considered as representative of current production and should not be treated as specifications. Data shown are subject to minor variations in normal manufacturing.**

1. *Determined on pure material.*
2. *Shell Thin Film Evaporometer, 25°C and 0% R.H.*
3. *8 gms. R.S. ½" N.C. (dry)/100 mls solvent.*
4. *At final concentration of 8 gms. R.S. ½" N.C. (dry)/100 mls combined solvent and diluent.*
5. *Tolu-Sol 17 or similar.*
6. *Shell Chemical Company products are shown in blue. Selected physical properties of all other products have been obtained wherever possible from published literature of their commercial producers.*
7. *% ester.*
8. *Donor-Acceptor.*
9. *25°C.*
10. *26°C.*
11. *78°F.*
12. *30°C.*
13. *Tag open cup.*
14. *Calculated from average compositional data.*
15. *Sets to glass below this temperature.*
16. *Closed cup.*
17. *15°C.*
18. *40°C.*
19. *Nitrocellulose blush.*
20. *Pensky-Martens closed cup.*
21. *Open cup.*
22. *Calculated from distillation data using Shell "Evapo-rator."*
23. *Tag closed cup.*
24. *Setaflash closed cup.*
25. *Calculated from ASTM-IP Petroleum Measurment Tables.*
26. *Toluene and Ethylbenzene.*
27. *NHB=Non-Hydrogen Bonding.*
28. *Wk Acc=Very weak acceptor.*

Table 2.138: Sunoco Chemicals Solvents *(12)*

Mineral Spirits - Toledo Refinery

Tests	Sales Specs	Typicals	Test Method
Composition, Vol. %			Sun GC-MS
Paraffins		48.0	
Olefins		0.2	
Napthenes		34.4	
Aromatics		17.4	
Benzene		<0.01	
Specific Gravity 60F/60F	0.782 Min - 0.799 Max	0.791	D891
Gravity, API		47.4	D287
Distillation, F			D86
IBP	300 Min - 330 Max	320	
End Point	395 Max	387	
Residue, Vol.%	1.5 Max	1.0	
Color, Saybolt	25 Min	30	D156
Appearance @ 65 - 78F	Clear	Clear	Visual
Flash Point, F	105 Min	110	D56
Kauri-Butanol Value	29.0 Min - 42.0 Max	39	D1133
Aniline Point, F	120 Min	126	D611
Total Sulfur, Wt. ppm	100 Max	4	D4045
Copper Corrosion		1A	D130
Bromine Number		<1	D1159

Meets ASTM D235 Type I Mineral Spirits (Stoddard Solvent).

Toluene (Nitration) - Toledo Refinery

Tests	Sales Specs	Typicals	Test Method
Composition, Vol. %			D2360 or Equivalent
Toluene		99.95	
Benzene	0.03 Max	<0.01	
C8 Aromatics		0.03	
Non-Aromatics	0.3 Max	0.02	
Specific Gravity 15.56C/15.56C	0.869 Min - 0.873 Max	0.872	D4052 or Equivalent
Distillation Range, C (including 110.6 C)	1.0 Max	0.6	D850 or Equivalent
Color, Pt-Co Scale	20 Max	5	D1209
Acid Wash Color	2 Max	0	D848
Appearance @ 65 - 78F	Clear	Clear	Visual
Total Sulfur, Wt. ppm	1.0 Max	<0.5	D4045
Sulfur Compounds (H2S and SO2)	None Detected	None Detected	D853
Copper Corrosion	Pass (1A or 1B)	Pass	D849
Acidity	None Detected	None Detected	D847
Bromine Index		<1	D1492
Water, Wt. ppm		60	D1744

Meets ASTM D841 specifications for Nitration Grade Toluene.

(continued)

Table 2.138: (continued)

Benzene - Toledo Refinery

Tests	Sales Specs	Typicals	Test Method
Composition, Wt. %			D4492 or Equivalent
Benzene		99.95	
Toluene		0.015	
Non-Aromatics	0.15 Max	0.035	
Specific Gravity 15.56C/15.56C	0.882 Min - 0.886 Max	0.883	D4052 or Equivalent
Distillation Range, C (including 80.1 C)	1.0 Max	0.6	D850 or Equivalent
Solidification Point, C	5.35 Min	5.49	D852
Color, Pt-Co Scale	20 Max	5	D1209
Acid Wash Color	1 Max	0	D848
Appearance @ 65 - 78F	Clear	Clear	Visual
Total Sulfur, Wt. ppm	1.0 Max	<0.1	D4045
Sulfur Compounds (H2S and SO2)	None Detected	None Detected	D853
Thiophene, Wt. ppm	1.0 Max	<1.0	D1685
Copper Corrosion	Pass (1A or 1B)	Pass	D849
Acidity	None Detected	None Detected	D847

Meets ASTM D2359 specifications for Refined Benzene - 535.

Sun does not test for Thiophene. However, we can conclude that chemically if sulfur is not greater than 0.4 ppm on a weight basis, then Thiophene cannot be greater than 1ppm.

CYCLOHEXANE - MARCUS HOOK, PA

Tests	Sales Specs	Typical •	Test Method
Composition			D3054
Cyclohexane, Wt. %	99.9 Min		
Benzene, Wt. ppm	20 Max		
Total Aromatics, Wt. ppm	150 Max		
Methylcyclopentane, Wt ppm	200 Max		
Methylcyclohexane, Wt ppm	200 Max		
Color, Saybolt	30 Min		D156
Total Sulfur, Wt ppm	1 Max		D4045
Total Chlorides, Wt ppm	1 Max		UOP 395-90
Non-Volatile Matter, mg/100 ml	1 Max		D1353
Free Water	None		Visual

Meets ASTM D3055, Cyclohexane 995 specifications.

(continued)

Table 2.138: (continued)

CUMENE - PHILADELPHIA, PA

Tests	Sales Specs		Typical •	Test Method
Cumene, Wt %	99.9	Max	99.95	D3760
Ethylbenzene, Wt ppm	50	Max	<5	D3760
N-Propylbenzene, Wt ppm	250	Max	166	D3760
Butylbenzene, Wt ppm	200	Max	93	D3760
Benzene, Wt ppm	20	Max	5	D3760
Diisopropylbenzene, Wt ppm	15	Max	2	D3760
Toluene, Wt ppm	5	Max	3	D3760
C8 - C9 Saturates, Wt ppm	100	Max	52	D3760
Methylstyrene, Wt ppm	Report		60	D3760
Cumene Hydroperoxide, Wt ppm	100	Max	43	D3703
Phenols, Wt ppm	5	Max	0.5	H952
Specific Gravity, 60°/60°F	0.864 - 0.867		0.865	D891
Color, Pt-Co Scale	15	Max	5	D1209
Acid Wash Color	2	Max	1	D848
Toltal Sulfur, Wt ppm	0.1	Max	0.03	D4045
Bromine Index	75	Max	44	D1492
Appearance	Clear		Clear	Visual

Meets ASTM D4077 specifications.

XYLENE - MARCUS HOOK, PA

Tests	Sales Specs	Typical •	Test Method
Composition, Vol %			D2360 or Equivalent
Total C_8Aromatics	---	99.8	
Paraxylene	---	23-26	
Metaxylene	---	51-57	
Orthoxylene	---	12-15	
Ethylbenzene	---	2-14	
Benzene	0.01 Max	<0.005	
Toluene	0.5 Max	0.07	
C9+ Aromatics	1.0 Max	<0.2	
Non-Aromatics	0.3 Max	0.02	
Specific Gravity, 15.56C/15.56C	0.865 Min 0.875 Max	0.872	D4052
Color (Pt-Co Scale)	20 Max	5	D1209
Distillation, ° C			D850 or Equivalent
Range(including 139.3° C)	5 Max	2.0	
IBP	137 Min	139.0	
Dry Point	143 Max	141.0	
Acid Wash Color	2 Max	0	D848
Acidity	Pass	Pass	D847
Total Sulfur, Wt ppm	1 Max	<0.1	D4045
Sulfur Compounds (H_2S and SO_2)	Pass	Pass	D853
Copper Corrosion	Pass	Pass	D849
Bromine Index	8 Max	1	D1492
Appearance, @ 65-78 °F	Clear	Clear	Visual
Water, Wt ppm	---	100	D1744
Non-volatile Matter, mg/100 ml	---	<1	D1353

Meets ASTM D843, nitration grade specifications.

Table 2.139: 3M SCOTCH-GRIP Solvents No. 2 and No. 3 *(54)*

Typical Physical Properties

	Solvent No. 2 Petroleum Distillate	Solvent No. 3 MEK
Solvent or Blend	N-Hexane and Toluene	(Methyl Ethyl Ketone)
Flash Point	-14°F. (TCC)	20°F. (TCC)
Net Weight (Approx.) (lbs./gal.)	6.3-6.7	6.65-6.75

Table 2.140: Total Petroleum Special Solvent *(52)*

HDF-201

Property	Test Method[1]	Typical	Requirement
Gravity, °API	D-1298	42	40.0 Min/44.0Max
Pounds per gallon @ 60°F			6.71 Min/6.87Max
Visual	Appearance @ 70°F		Clear & Bright
Haze	D-4176		1 Max.
Color Saybolt	D-156	+30	+24 Minimum
Flash PM °F	D-93	206	201 Min/211 Max.
Viscosity, 104°F, cst	D-445	2.0	1.6 Min/2.4 Max.
Aniline Point, °F.	D-611	Report	
Kauri-Butanol Value	D-1133	Report	
Distillation, °F	D-86		
Initial Boiling Point		425	405 Min/445Max
50% Recovered		460	435 Min/485 Max.
Final Boiling Point		480	450 Min/510 Max.
Pour, °F	D-97		-10 Max.
Sulfur, wt.%	D-4294		.005 Max.
Mutation Assay	Ames Test(2)	Pass (negative)	
Ultraviolet absorbance	21CFR 178.3620(c)	Pass	
U.S. Dept. of Agriculture Authorization		Pass	

(1) ASTM Standard Test Methods

(2) Modified Salmonella/Microsome

(continued)

Table 2.140: (continued)

HDF 300

Property	Test Method[1]	Typical	Requirement
Gravity, API	D-1298	40	37.0 Min/41.0 Max
Pounds per gallon @ 60F			6.83 Min/6.992 Max
Visual	Appearance @ 70F		Clear & Bright
Haze	D-4176		1 Max
Color Saybolt	D-156	28	+20 Minimum
Flash COC F	D-92	275	265 Minimum
Viscosity, SUS @ 104F	D-2161	41	37 Min/44 Max
Aniline Point, F.	D-611	189	
Kauri-Butanol Value	D-1133	23	
Distillation, F	D-86		
Initial Boiling Point		530	480 Min/550 Max
50% Recovered		560	540 Min/580 Max
Final Boiling Point		605	580 Min/630 Max
Benzene	GC	N.D.[2]	
Mutation Assay	Ames Test[3]		Pass (negative)
Ultraviolet absorbance	21CFR 178.3620(c)		Pass
U.S. Dept. of Agriculture Authorization			Acceptable

(1) ASTM Standard Test Methods
(2) Non-detectable with detection limit of 0.5 ppmw
(3) Modified Salmonella/Microsome

HEXENES

Property	Test Method[1]	Requirement
Gravity, API	D-1298	70 Min/80 Max
Olefin Content, Vol. %	D-1319	85 Minimum
C_6 Hydrocarbons, Wt. %	D-5134[2]	97 Minimum
Total Sulfur, ppmw	D-4045	20 Maximum
Total Chlorides	UOP 395-79	5 Maximum
Uniroyal Naugard (TM) BHT, ptb	--	10

This product contains no other gasoline components or gasoline additives.

(1) ASTM Standard Test Methods, unless otherwise specified.

(2) Modified for carbon number separation of olefinic material.

(continued)

Table 2.140: (continued)

P-P MIX (Refinery Grade)

Property	Test Method[1]	Typical	Requirement
Vapor Pressure @ 100°F., psig	D-2598	206	213 Maximum
Volatile Residue:			
Evaporated Temperature, 95%	D-1837	-40	-37 Maximum
or			
Butane and Heavier Percent	D-2163	0 - 1.0	2.0 Maximum
Residual Matter:			
Residue on Evaporation of 100 ml	D-2158	<.05	0.05 Maximum
Oil Stain Observation	D-2158	Pass	Pass
Total Sulfur, ppmw	D-4045	0 - 2	10 Maximum
Hydrogen Sulfide	D-2420	Pass	Pass
Corrosion Copper Strip	D-1838	1	No. 1 Maximum
Moisture Content	D-2713	Pass	Pass
Composition (Mole Percent):	D-2163		
Propylene		80	70 Minimum
Propane		19	30 Maximum
Ethane and lighter		.1	1.0 Maximum

(1) ASTM Standard Test Methods

220 FLASH SOLVENT

Property	Test Method(1)	Typical	Requirement
Gravity, °API	D-1298	41	40.0 Min/44.0 Max
Pounds per gallon @ 60°F			6.71 Min/6.87 Max
Visual	Appearance @ 70°F		Clear & Bright
Haze	D-4176		1 Max
Color Saybolt	D-156	+30	+20 Minimum
Flash COC °F	D-92	230	220 Minimum
Flash PM °F	D-93	214	210 Minimum
Viscosity, 104°F, cst	D-445	2.7	1.6 Min/2.8 Max
Aniline Point, °F.	D-611	174	
Kauri-Butanol Value	D-1133	28	
Distillation, °F	D-86		
Initial Boiling Point		460	450 Min/490 Max
50% Recovered		490	465 Min/515 Max
95% Recovered		515	470 Min/520 Max
Final Boiling Point		530	500 Min/560 Max
Benzene	GC	N.D.(2)	
Mutation Assay	Ames Test(3)	Pass (negative)	
Ultraviolet absorbance	21CFR 178.3620(c)	Pass	
U.S. Dept. of Agriculture Authorization		Acceptable	

(1) ASTM Standard Test Methods
(2) Non-detectable with detection limit of 0.5 ppmw
(3) Modified Salmonella/Microsome

Table 2.141: UCAR Solvents *(19)*

Typical Physical Properties of UCAR Solvents

	Solvent	Molecular Weight	Density at 20°C, lb/gal	Boiling Point, °C	Relative Evaporation Rate (BuAc=100)	Vapor Pressure at 20°C, mm Hg	Heat of Vaporization at 760 mm Hg, BTU/lb	Flash Point, Closed Cup, °F	Total Solubility Parameters	Heat of Combustion at 25°C, Kcal/Mole	Viscosity at 20°C, cP
Alcohols	Ethanol	46.07	6.76	78.3	333	45	361	58	12.78	-326.85	1.2
	1-Propanol	60.10	6.71	97.2	133	15	297	74	12.18	-482.75	2.2
	Isopropanol	60.10	6.55	82.3	288	33	295	53	11.44	479.44	2.4
	Butanol	74.12	6.75	117.7	44	4	254	95	11.60	-639.60	3.0
	Isobutanol	74.12	6.68	107.9	74	7	248	82	11.24	-637.93	4.0
	1-Pentanol	88.15	6.79	137.8	18	2	218	119	10.83	-795.10	3.9
	2-Ethylhexanol	130.23	6.94	184.6	<1	<1	153	162	10.15	-693.37	10.3
Esters	*Ethyl Acetate*	88.11	7.51	77.2	747	76	155	30	8.91	537.50	0.5
	n-Propyl Acetate	102.13	7.39	101.5	279	26	144	58	8.80	693.37	0.6
	Isopropyl Acetate	102.13	7.26	88.9	501	47	142	42	8.58	-691.10	0.5
	Butyl Acetate	116.16	7.34	126.2	100	15	135	84	8.69	828.60	0.7
	Isobutyl Acetate	116.16	7.24	118.0	172	4	131	62	8.43	–	0.7
	Primary Amyl Acetate	130.19	7.29	146.0	49	2	211	101	8.34	-1058.00	0.9
	Methyl PROPASOL® Acetate	132.16	8.09	145.7	34	3	–	116	8.43	–	1.2
	Butyl CELLOSOLVE® Acetate	160.21	7.84	192.3	3	<1	118	165	8.91	-1122.38	1.8
	UCAR® Ester EEP	146.19	7.91	169.7	11	<1	–	136	9.00	–	1.3
Glycol Ethers	Butyl CELLOSOLVE® Solvent	118.18	7.51	171.2	6	<1	158	150	9.87	-914.25	6.4
	Methyl CARBITOL® Solvent	120.16	8.51	194.0	<1	<1	170	188	11.15	–	3.9
	CARBITOL® Solvent	134.18	8.25	202.7	<1	<1	151	182	10.34	878.84	4.5
	Butyl CARBITOL® Solvent	162.23	7.96	230.6	<1	<1	132	214	9.79	-1190.58	6.5
Ketones	Acetone	58.08	6.59	56.3	1440	185	219	0	9.62	427.77	0.3
	Methyl Ethyl Ketone	72.11	6.71	79.6	631	71	187	24	9.45	-582.80	0.4
	Methyl Isobutyl Ketone	100.16	6.67	116.1	162	15	147	61	8.58	735.60	0.6
	Methyl n-Amyl Ketone	114.19	6.81	151.5	40	2	148	102	8.98	985.19	0.8
	Diacetone Alcohol	116.16	7.82	169.2	12	<1	154	117	9.78	847.40	3.2
	Isophorone	138.21	7.67	215.3	2	<1	135	179	9.36	1234.35	2.6
	Diisobutyl Ketone	142.24	6.72	169.4	17	1	119	118	8.06	1359.20	1.0

(continued)

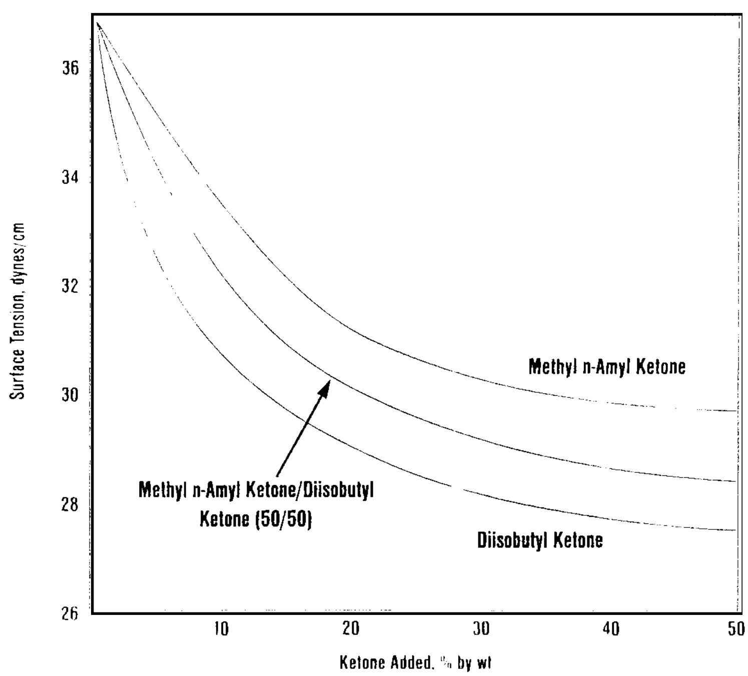
Table 2.141: (continued)

UCAR Solvents for Electrostatic Coatings* Resistivity (Megohms)

Alcohols		Esters	
Ethanol (200 proof)	0.03	Butyl CELLOSOLVE® Acetate	3.00
Primary Amyl Alcohol	0.10	Butyl Acetate	3.50
1-Propanol	0.18	Isobutyl Acetate	5.00
Butanol	0.18	Isopropyl Acetate	7.00
Isobutanol	0.18	n-Propyl Acetate	10.00
Isopropanol (anhydrous)	0.35	Ethyl Acetate	18.00
2-Ethylhexanol	8.00	Primary Amyl Acetate	>20.00

Glycol Ethers		Ketones	
CARBITOL® Solvent (low gravity)	0.03	Acetone	0.04
Methyl CARBITOL® Solvent	0.03	Diacetone Alcohol	0.06
Butyl CELLOSOLVE® Solvent	0.06	Isophorone	0.08
Butyl CARBITOL® Solvent	0.13	Methyl Ethyl Ketone	0.13
		Methyl Isobutyl Ketone	0.45
		Methyl n-Amyl Ketone	0.75
		Diisobutyl Ketone	1.50

Surface Tension Reduction of a Higher Solids Acrylic Resin *(19)*



(continued)

Table 2.141: (continued)

Surface Tension of UCAR Solvents *(19)*

	Solvent	Surface Tension, dynes/cm
Ketones	Diisobutyl Ketone	22.2
	Methyl Isobutyl Ketone	23.6
	Methyl Ethyl Ketone	24.6
	Methyl n-Amyl Ketone	26.1
	Diacetone Alcohol	31.0
	Isophorone	32.0
Esters	Isopropyl Acetate	22.3
	Isobutyl Acetate	23.6
	Ethyl Acetate	23.7
	n-Propyl Acetate	24.3
	Primary Amyl Acetate	25.2
	Butyl Acetate	25.4
	Butyl CELLOSOLVE® Acetate	27.4
Glycol Ethers	Butyl CELLOSOLVE® Solvent	28.6
	Butyl CARBITOL® Solvent	31.0
	Methyl CARBITOL® Solvent	35.9

Influence of Letdown Solvents[1] *(19)*

Solvent	Coating Surface Tension, dynes/cm	Solvent Surface Tension, dynes/cm
Diisobutyl Ketone	39.0	22.5
Diacetone Alcohol	44.0	31.0
Isopropanol	46.5	21.4
Ethylene Glycol	55.5	48.4

(1) *Industrial Higher-Solids Coatings, Present and Future*, A. Heitkamp, et al, High Solids Coatings, December 1980.

Table 2.142: Unocal Aliphatic and Aromatic Hydrocarbons *(13)*

Aliphatic Hydrocarbons

Product Name	Chemical Abstract Service Number	Gravity 60°F (15.56°C) API	Specific	lb/gal	Distillation Range, °F (°C) IBP	DP	Vapor Pressure @ 20°C mmHg	Coefficient of Expansion (Per °C)	Relative Evap. Rate n-BuAc = 1	Aniline Cloud Pt., °F (°C)	Kauri-Butanol Value	Flash Point, TCC, °F	% Hydrocarbon Composition Aromatics	Paraffins	Cycloparaffins
Rubber Solvent	64742-89-8	71.8	0.696	5.79	118 (47.8)	275 (135.0)	180	0.0013	6.1	141 (60.6)	34	<0	4	75	21
Textile® Spirits	64741-84-0	77.6	0.677	5.63	149 (65.0)	183 (79.8)	115	0.0013	8.8	147 (63.9)	29	<0	<1	89	11
Hexane	110-54-3	77.8	0.676	5.63	151 (66.1)	158 (70.0)	140	0.0015	8.1	151 (66.1)	30	<0	Nil	89	11
Heptane	142-82-5	71.9	0.696	5.79	199 (93)	210 (98.9)	45	0.0011	4.5	155 (68.3)	30	15	Nil	89	11
Lactol® Spirits	64742-89-8	57.9	0.747	6.22	202 (94.4)	222 (105.6)	40	0.0011	3.9	109 (42.8)	42	20	12	42	46
Roto Solv	8032-32-4	61.8	0.732	6.09	241 (116.1)	249 (120.6)	17	0.0011	1.7	145 (62.8)	34	45	5	60	35
Special Naphtholite® 66/3 (VM&P)	8032-32-4	54.9	0.759	6.32	265 (126.7)	291 (143.9)	5.2	0.0011	1.0	143 (61.7)	35	65	<1	42	57
Naphthol Spirits 66/3*	8052-41-3	50.9	0.776	6.46	318 (158.9)	355 (179.4)	2.9	0.0008	0.21	152 (66.7)	33	105	<1	44	55
Regular Mineral Spirits	8052-41-3	48.1	0.788	6.56	315 (157.2)	385 (196.1)	3.1	0.0009	0.12	133 (56.1)	37	108	16	46	38
Mineral Spirits 75*	8052-41-3	49.0	0.784	6.53	315 (157.2)	395 (201.7)	3.0	0.0009	0.13	148 (64.4)	34	107	<8	48	44
Mineral Spirits 66/3*	8052-41-3	50.4	0.778	6.48	321 (160.6)	382 (194.4)	2.6	0.0009	0.13	155 (68.3)	33	108	<1	47	52
1-K Kerosine	8008-20-6	41.2	0.819	6.82	345 (173.9)	525 (273.9)	1.8	0.0010	0.01	144 (62.2)	34	145	18	41	41
Odorless Mineral Spirits	8052-41-3	54.3	0.762	6.34	358 (181.0)	407 (208.0)	1.2	0.0011	0.17	188 (87.0)	26	125	Nil	99+	Nil
460 Solvent	—	43.8	0.807	6.72	372 (188.9)	503 (261.7)	<1	0.0009	0.02	153 (67.2)	33	140	8	56	36
142 Solvent 66/3‡	8052-41-3	46.7	0.794	6.61	378 (192.2)	401 (205.0)	<1	0.0009	0.08	162 (72.2)	31	145	<1	45	54
Mineral Spirits 150 66/3‡	8052-41-3	46.4	0.795	6.62	384 (195.6)	408 (208.9)	<1	0.0009	0.07	161 (71.7)	32	154	1	44	55

® Registered Trademark of Unocal
* Meets Dry Cleaning Fluid Specification PD680, Type I.
‡ Meets Dry Cleaning Fluid Specification PD680, Type II.

Mineral Spirits (Stoddard Solvent) type per ASTM D 235-96

Product Name	ASTM Type
Naphthol Spirits 66/3	IV C
Regular Mineral Spirits	I A
Mineral Spirits 75	I B
Mineral Spirits 66/3	I C
Odorless Mineral Spirits	III C
142 Solvent 66/3	II C
Mineral Spirits 150 66/3	II C

The following products meet, at a minimum, the UV requirements of FDA regulation (21 CFR):

Hexane 175.105
Heptane 172.882, 175.105, 178.3530
Special Naphtholite 66/3 (VM&P) 172.882, 175.105, 178.3530
Naphthol Spirits 66/3 175.105, 178.3620, 178.3910
Mineral Spirits 66/33 172.882, 172.884, 175.105, 178.3910
Odorless Mineral Spirits 172.882, 175.105, 178.3650, 178.3910
142 Solvent 66/3 175.105, 178.3620, 178.3910
Mineral Spirits 150 66/3 175.105, 178.3620, 178.3910

Aromatic Hydrocarbons

Product Name	Chemical Abstract Service Number	Gravity 60°F (15.56°C) API	Specific	lb/gal	Distillation Range, °F (°C) IBP	DP	Vapor Pressure @ 20°C mmHg	Coefficient of Expansion (Per °C)	Relative Evap. Rate n-BuAc = 1	Aniline Cloud Pt., °F (°C)	Kauri-Butanol Value	Flash Point, TCC, °F	% Hydrocarbon Composition Aromatics	Paraffins	Cycloparaffin
Toluene	108-88-3	30.8	0.872	7.26	230 (110.3)	231 (110.8)	23.8	0.0011	1.90	48 (8.9)	105	45	100	Nil	Nil
Xylene	1330-20-7	30.9	0.871	7.25	280 (137.7)	285 (140.7)	6.6	0.0010	0.80	50 (10.0)	98	81	100	Nil	Nil
Super Hi-Flash Naphtha	64742-95-6	30.6	0.873	7.27	315 (157.2)	347 (175.0)	2.7	0.0008	0.37	56 (13.3)	91	112	100	Nil	Nil
Solv G	64742-94-5	26.2	0.897	7.47	363 (183.9)	413 (211.7)	<1	0.0008	0.13	60 (15.6)	94	149	100	Nil	Nil

(continued)

Table 2.142: (continued)

MINERAL SEAL OIL

PRODUCT DESCRIPTION

Unocal Hydrocarbon Sales Mineral Seal Oil is a highly refined, hydrotreated paraffinic light oil that is water-white in appearance. Properties include a very low odor, low aromatic content and low pour point. This product meets 21CFR178.3620(c).

		Specifications	Typical Properties	* ASTM Test
PRODUCT CODE		2540		
API GRAVITY (60/60 F)	DEGF		35.7	D-287
DISTILLATION, IBP	DEGF		493	D-86
DISTILLATION, 50%	DEGF		516	D-86
DISTILLATION,END POINT	DEGF		563	D-86
SPECIFIC GRAVITY (60/60 F)		0.830-0.860	0.845	D-1298
DENSITY @ 60 F (15.6 C)	LB/GAL	6.93-7.18	7.05	CALC'D
VISCOSITY, 40C	cst	3.0-4.0	3.40	D445/216
VISCOSITY, 100C	cst		1.31	D445/216
VISCOSITY, 100F	SUS	36-40	37.8	D445/216
ANILINE POINT	DEGF		170	D-611
FLASH POINT (COC)	DEGF	248 MIN	259	D-92
COLOR, SAYBOLT	SAYBOLT	+20 MIN	30	D-156
AROMATIC CONTENT	WT%		<3	GC
SULFUR CONTENT	PPM		<1	D-4084
CLOUD POINT	DEGF	-4 MAX	-22	D-2500
APPEARANCE @ 70 DEGF		Clear & Bright	C & B	
POUR POINT	DEGF	-6 MAX	-27	D-97

RETARDSOL

PRODUCT DESCRIPTION

Unocal Hydrocarbon Sales Retardsol is a water-white kerosine that meets ASTM 2-K specifications. Kerosine consists primarily of C10-C16 aliphatic and aromatic hydrocarbons and is widely used as heating oil and diesel fuel. Because of its high solvency and high flash point Unocal Hydrocarbon Sales Retardsol finds many commercial applications in general cleaning solvents and in agricultural sprays. Specifications and typical properties are listed below.

		Specifications	Typical Properties	* ASTM Test
MANUFACTURER		LEMONT REFINRY		
PRODUCT CODE		2019		
API GRAVITY (60/60 F)		39-51	40.7	D-287
DISTILLATION, IBP	DEGF		320	D-86
DISTILLATION, 10%	DEGF	347-400	390	D-86
DISTILLATION, 50%	DEGF	450 MAX	430	D-86
DISTILLATION, DP	DEGF	550 MAX	510	D-86
SPECIFIC GRAVITY (60/60 F)			0.8215	D-1298
DENSITY @ 60 F (15.6 C)	LB/GAL		6.84	CALC'D
VAPOR PRESSURE @ 20 C	mm Hg		0.1	
VISCOSITY @ 20 C	cst		2.117	D-445
KAURI-BUTANOL VALUE (KB)			34	D-1133
ANILINE POINT	DEGF		141	D-611
FLASH POINT (TCC)	DEGF	110 MIN	123	D-56
COLOR, SAYBOLT		+22 MIN	27	D-156
DOCTOR TEST			NEGATIVE	D-235
CORROSION, 3 HRS @ 212 F			1A	D-130
PARAFFINS	VOL%		42	GC-MS
CYCLOPARAFFINS	VOL%		38	GC-MS
AROMATIC CONTENT	VOL%	20 MAX	19	GC
BENZENE CONTENT	VOL%		0.01	D-2600
OLEFINS	VOL%		0.5	D-1159
SULFUR CONTENT	WT%	0.20 MAX	0.03	D-4084
REFRACTIVE INDEX @ 20 C			1.4952	D-1218
SOLUBILITY PARAMETER	(cal/cc)1/2		7.9	

Table 2.143: Vista LPA Solvents *(40)*

Typical Properties of Vista LPA Solvents

Typical Properties	*Vista LPA*	*Vista LPA-110**	*Vista LPA-142*	*Vista LPA-170*	*Vista LPA-210*	*Vista-47*
Distillation Range, °F,						
IBP	362	335	368	413	465	464
10%	388	340	372	420	474	472
20%	392	341	373	422	475	474
50%	412	345	377	424	479	479
90%	460	355	386	431	495	497
95%	476	360	389	434	506	508
EP	516	385	405	458	539	531
Flash Point,						
Tag Closed Cup, °F	148	112	146	178	—	—
Pensky Martens, °F	—	—	—	—	226	228
Freeze Point, °F	-90	<-103	<-103	-81	-43	0
Pour Point, °F	-95	<-112	<-112	-92	-45	0
Specific Gravity 60°/60°F	.809	.794	.809	.811	.823	.812
Density, lbs/gal. @ 60°F	6.75	6.63	6.75	6.77	6.87	6.78
Average Molecular Weight	167	141	152	171	194	197
Average Composition						
% Paraffinic	46	25	27	58	65	72
% Naphthenic	54	75	73	42	35	28
% Aromatic	0.2	0.1	0.2	0.5	0.6	0.7
Color, Saybolt Universal	+30	+30	+30	+30	+20	+20
Relative Evaporation Rate (n-Butyl Acetate=1)	0.02	0.19	0.09	0.03	0.004	<0.004
Vapor Pressure, mm Hg						
100°F	1.0	2.0	1.1	0.37	0.10	0.10**
Viscosity, cSt						
70°F	2.2	1.4	1.8	2.4	3.8	3.8
100°F	1.6	1.1	1.4	1.8	2.6	2.6
Aniline Point, °F	160	137**	142**	160	170	180
Kauri Butanol Value	32	36	35	32	29	27
Solubility parameters**, $(Cal/cm^3)^{0.5}$	8.1	8.0	8.1	8.1	7.9	7.8
Bromine Number	<.2	<.2	<.2	<.2	<.2	<.2
Carbonyl, as C=O ppm	<10	<10	<10	<10	<10	<10
Nitrogen, ppm	<1	<1	<1	<1	<1	<1
Sulfur, ppm	<1	<1	<1	<1	<1	<1
Water, ppm	<50	<50	<50	<50	<50	<50

Vista MR Solvent *(40)*

Description

Vista MR Solvent is a highly refined hydrocarbon in the kerosene boiling range. It is colorless, has a mild odor, low viscosity, and a typical aromatics content of 15%. MR Solvent has an extremely low sulfur and nitrogen content. The unique process used to produce MR Solvent yields low levels of normal paraffins. Consequently, MR Solvent has a higher solvent strength and lower freeze point than competitive solvents with equivalent boiling ranges.

Distillation Range, °F, (ASTM D-86)	
IBP	370
10%	390
20%	400
50%	420
90%	475
95%	480
EP	510
Flash Point,	
Tag Closed Cup, °F	148
Pensky Martens, °F	154
Freeze Point, °F	<-90
Pour Point, °F	<-95
Specific Gravity 60°/60°F	0.817
Density, lbs/gal. @ 60°F	6.82
Average Molecular Weight	170
Average Composition	
% Paraffinic	45
% Naphthenic	40
% Aromatic	15

Color, Saybolt Universal	+30
Relative Evaporation Rate (n-Butyl Acetate=1)	0.02*
Vapor Pressure, mm Hg	
100°F	1.2
Viscosity, cSt	
70°F	2.1
100°F	1.6
Aniline Point, °F	145
Kauri Butanol Value	33
Solubility parameter* $(Cal/cm^3)^{0.5}$	8.1
Cetane Number	43
Bromine Number	<0.2
Carbonyl, as C=O ppm	<10
Nitrogen, ppm	<1
Sulfur, ppm	<1
Water, ppm	<50

*Estimate

(continued)

Table 2.143: (continued)

Vista C14 Normal Paraffin

Description:
Vista C_{14} n-paraffin is a high purity, linear saturated paraffin. It is a clear, low odor, low viscosity liquid.

Properties	Specification	Typical
Total n-paraffin, Wt.%	96.5	96.5-98.0
Hydrocarbon Distribution (Wt.%)		
$\leq C_{13}$	11 max	6-10
C_{14}	87 min	87-90
$\geq C_{15}$	2.5 max	1-2
Average Molecular Weight	–	197-201
Aromatics, Wt.%	1.5 max	0.9
Bromine Number	0.04 max	0.025
Color Saybolt	+20 min	+25 - +30
Specific Gravity, 15° C/15° C	–	0.768
Density at 60° F, lb/gal	–	6.40
Flash Point, (PM) °C/ °F	93/200 min	109-114° C/229-237° F
Melting Point, °C/ °F	–	4/40
Viscosity cSt @ 40° C/104° F	–	2.1
Distillation Range, °C/ °F		
IBP	–	244/472
EP	–	251/484
Appearance	–	Clear Liquid

Vista C1416 n-Paraffin Solvent

Description:
Vista C1416 n-paraffin is a high purity, linear saturated paraffin blend of various molecular weights in the C13-C17 carbon range. It is a clear, straw colored, low odor, low viscosity liquid.

Properties	Specification	Typical
Total n-Paraffin, wt.%	96.5	97.0
C13 and Lower	5.0 max	1.0
C14	—	26.5
C13 + C14	—	—
C15	—	53.5
C16	—	14.0
C17 +	6.0 max	5.0
Average molecular weight	—	211
Aromatics, wt.%	1.5 max	0.9
Bromine Number	0.04 max	0.025
Color, Saybolt	− 16 min	+ 10
Specific Gravity, 25°C	—	0.775
Flash point, °F	—	250
Melting Range, °C	—	8
Viscosity @ 100°F cSt	—	2.7
Distillation range, °F	—	—
IBP	—	487
50%	—	493
95%	—	511
EP	—	547
Appearance	—	Clear
	—	Straw
	—	Liquid

Halogenated Hydrocarbons

CHLORINATED HYDROCARBONS

Table 3.1: Allyl Chloride *(7)*

3-Chloropropene-1 — $CH_2{=}CHCH_2Cl$

PHYSICAL PROPERTIES

Boiling point	45°C
Fire point	4°C
Flash point	4°C
Latent heat of vaporization	84.6 cal/g
Specific gravity @25/25°C	0.933
Specific heat	0.31 cal/g/°C
Refractive index @25°C	1.412
Viscosity @25°C	0.33 centipoise
Weight per gallon @25°C	7.8 lb

Table 3.2: n-Amyl Chloride *(7)*

1-Chloropentane — $CH_3CH_2CH_2CH_2CH_2Cl$

PHYSICAL PROPERTIES

Acidity as HCl	0.025% max.
Amylene	1% max.
Boiling range	105-109°C
Distillation	95% between 104.9-108.9°C
Flash point	54°F
Other hydrocarbons	None
Polychlorides content	None
Solubility in water	Insoluble
Specific gravity @20/20°C	0.885
Weight per gallon	7.38 lb

Table 3.3: Mixed Amyl Chlorides *(7)*

$C_5H_{11}Cl$

PHYSICAL PROPERTIES

Acidity as HCl	0.03% max.
Amylene and pentane content	3.0% max.
Boiling point (approx.)	
1-Chloropentane	108.2°C
2-Chloropentane	96.7°C
3-Chloropentane	97.3°C
1-Chloro-2-methylbutane	99.9°C
4-Chloro-2-methylbutane	98.8°C
3-Chloro-2-methylbutane	93.0°C
2-Chloro-2-methylbutane	86.0°C

Distillation range		95% between 85-109°C
Evaporation rate @108°F:	Minutes	
	1.30	25%
	1.67	50%
	4.30	75%
	6.58	100%
Flash point (O.C.)		34°F
Kauri-butanol value		71 cc
Solubility in water		Negligible
Specific gravity @20°C		0.88
Vapor pressure @20°		42.8 mm
Water azeotrope @77-82°C		90% $C_5H_{11}Cl$ (approx.)
Weight per gallon		7.33 lb

Table 3.4: Benzyl Chloride *(7)*

α-Chlorotoluene $C_6H_5-CH_2-Cl$

PHYSICAL PROPERTIES

Distillation range	Not more than 2° including 179.4°C
Freezing point	-43°C
Molecular weight	126.58
Refractive index N_D^{25}	1.5365
Specific gravity @15.5°/15.5°C	1.107
Weight per gallon @15.5°C	9.23 lb

Table 3.5: n-Butyl Chloride *(7)*

PHYSICAL PROPERTIES

Acidity	0.01% max.
Boiling point @760 mm	78°C
Distillation range	Not less than 95% between 76.0-79.5°C
Flash point (O.C.)	20°F
Latent heat of vaporization @76.5°C	79.8 cal/g
Melting point	-123.1°C
Refractive index @20°C	1.4004
Solubility in water	Negligible
Specific gravity @20/4°C	0.884
Specific heat @20°C	0.451 cal/g
Surface tension @20°C	23.66 dynes/cm
Water content	None
Weight per gallon	7.37 lb

n-BUTYL CHLORIDE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
80	Acetone	55.8
1.9	n-Butyl alcohol	77.7
57	n-Butyl nitrite	76.5
35	Ethyl acetate	76.0
20.	Ethyl alcohol	65.7
4	Isobutyl alcohol	77.7
62	Isobutyl nitrite	66.2
23	Isopropyl alcohol	70.8
29	Methyl alcohol	57.0
38	Methyl propionate	76.8
40	Methyl propyl ketone	77.0
16	Nitromethane	75.0
18	n-Propyl alcohol	74.8
38	n-Propyl formate	76.1
6.6	Water	68.1

Table 3.6: sec-Butyl Chloride *(7)*

FORMULA	$CH_3-CH(Cl)-CH_2-CH_3$
PROPERTIES	98.0% GRADE
Composition, weight percent	
secondary-Butyl Chloride	99.5
Butenes	0.5
Purity by freezing point, mol %	
Freezing point, F	
Boiling point, F	
Distillation range, F	
Initial boiling point	151
10% Condensed	
50% Condensed	154
90% Condensed	
Dry point	156

PROPERTIES	98.0% GRADE
Specific gravity of liquid at 60/60 F	0.879
at 20/4 C	0.875
API gravity at 60 F	29.5
Density of liquid at 60 F, lbs/gal	7.32
Refractive index, 20/D	1.396
Color, Saybolt	
Acidity, distillation residue	
Nonvolatile matter, grams/100 ml	
Color Alpha	10
Flash point, approximate, F	< 80
Flammability limits, volume % in air	
Lower	
Higher	

*Literature values.

Table 3.7: Butyryl Chloride *(27)*

Butanoyl Chloride C_3H_7COCl

Butanoyl chloride is a clear colorless liquid with a characteristic pungent odor. It reacts with water and alcohol and is infinitely soluble in ether. It is used for organic synthesis to introduce the butyryl group.

PHYSICAL PROPERTIES

Molecular Weight	106.5
Freezing Point	-89°C
Boiling Point	102°C
Distillation Range	100° to 110°C
Refractive Index n20/D	1.4121
Specific Gravity, 15.5°/15.5°C	1.028
Pounds per Gallon at 15.5°C	8.56

Table 3.8: Caprylyl Chloride *(27)*

Octanoyl Chloride $CH_3(CH_2)_6COCl$

Caprylyl chloride is a water-white to straw-colored liquid with a pungent odor. It usually contains small quantities of hexanoyl and decanoyl chlorides.

PHYSICAL PROPERTIES

Molecular Weight	162.7
Chlorine Content (typical)	21.8%
Freezing Point	<-70°C
Pour Point	<-70°C
Distillation Range(1)	183° to 212°C
Refractive Index, n20/D	1.4357
Flash Point (Cleveland open cup)	82°C
Fire Point (Cleveland open cup)	87°C
Specific Gravity, 15.5°/15.5°C	0.955
Pounds per Gallon at 15.5°C	7.96
Density Correction Factor, gm/cc/1°C	0.00085
Coefficient of Cubical Expansion at 15.5°C/1°C	0.00096

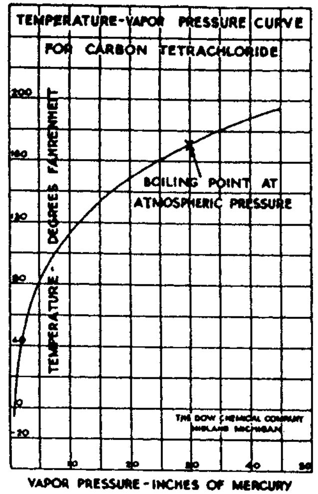
(1) Typical ASTM distillation to 90%. Decomposition occurs beyond this point.

Table 3.9: Carbon Tetrachloride *(7)*

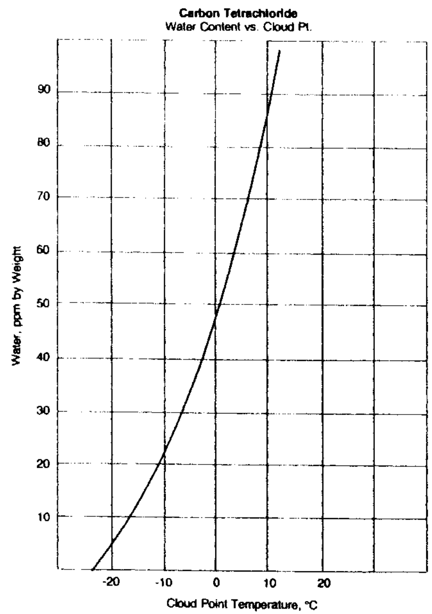
Tetrachloromethane CCl_4

PHYSICAL PROPERTIES

Acidity as HCl	None
Boiling point @760 mm	76.7°C (170.1°F)
Boiling range	Within 1°C
Coefficient of cubical expansion Av./°C, liquid	0.00127
Dielectric constant, 1000 cycle	2.24
Electrical conductivity	4 x 10^{-18} recip. ohm
Fire point	Nonflammable
Flash point	Nonflammable
Freezing point	-23°C
Heat of fusion	4.2 cal/kg
Heat of vaporization	46.5 cal/g
Power factor, 1000 cycle	0.057%
Purity	99.99% min.
Refractive index @20°C	1.4607
Residue	0.0010% by wt, max.
Solubility in water @20°C	0.08% by wt
Solubility of water in solvent @20°C	0.008 % by wt
Specific gravity @25/4°C	1.5845
Specific heat Liquid, 25°	0.1995 cal/g/°C
76.8°C	0.2157 cal/g/°C
Specific resistivity	3.8 x 10^{12} ohms/cm
Thermal expansion per °C	0.127% (of liquid @158°F)
Vapor density (B.P., 760 mm)	5.37 g/liter
Vapor pressure @30°C	140 mm
Viscosity liquid @20°C	0.96 centipoise
Weight per gallon @25°C	13.22 lb



Temperature-Vapor Pressure Curve
for Carbon Tetrachloride



CARBON TETRACHLORIDE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
88.5	Acetone	56.4
	Acetonitrile	71
3	Acetic acid	76.55
21	Acrylonitrile	66.2
11.5	Allyl alcohol	72.3
71	2-Butanone	73.8
4.5	tert-Amyl alcohol	76.6
2.5	Butyl alcohol	76.6
7.6	sec-Butyl alcohol	74.6
24	tert-Butyl alcohol	70.5
35	Butyl nitrite	74.8
21	1,2-Dichloroethane	75.6
43	Ethyl acetate	74.8
15.85	Ethyl alcohol	61.1
15.5	Ethyl nitrate	75
81.5	Formic acid	66.65
5.5	Isobutyl alcohol	75.8
12	Isopropyl alcohol	69
20.56	Methanol	55.7
25	Methyl propionate	76
17	Nitromethane	71.3
11.5	Propyl alcohol	73.1
31	Propyl formate	74.6
4.1	Water	66

Table 3.10: Chlorinated Butane Derivatives *(73)*

Physical Properties of Intermediates and Products

Compound	B.P., °C., corr.	Press., mm.	Density d^{25}	Refractive Index, N_D^{25}	Chlorine, %[1] Found	Chlorine, %[1] Calcd.
1-Chlorobutane	77.5-78.5	745		1.3995		
1,1-Dichlorobutane	114.8-115.1	752	1.0797	1.4305		
1,2-Dichlorobutane	122.9-123.3	743	1.1118	1.4425		
1,3-Dichlorobutane	133.0-133.2	744	1.1083	1.4414		
1,4-Dichlorobutane	154.1-154.2	749	1.1324	1.4522		
1,1,1-Trichlorobutane	133.1-133.3	750	1.2242	1.4483	65.76	65.88
1,1,2-Trichlorobutane	156.3-156.8	746	1.2787	1.4667	65.95	65.88
1,1,3-Trichlorobutane	153.2-153.8	750	1.2514	1.4593	65.92	65.88
1,1,4-Trichlorobutane	183.6-183.8	754	1.2967	1.4753	65.92	65.88
1,1,1,2-Tetrachlorobutane	69.1-69.4	20.0	1.3952	1.4812	72.63	72.39
1,1,1,3-Tetrachlorobutane	69.5-69.8	20.0	1.3747	1.4772	72.18	72.39
1,1,1,4-Tetrachlorobutane	86.8-87.1	20.0	1.4001	1.4858	72.81	72.39
1,1-Dichloro-1-butene	103.3-103.5	747		1.4465	56.21[2]	56.74
α-Chlorobutyraldehyde	106-108[3]	740		1.441	35.38	33.28
n-Butyryl chloride	101-101.5[3]	745		1.4098		
α-Chlorobutyryl chloride	51.5-51.7	40.0		1.4410		
β-Chlorobutyryl chloride	53.0-53.3	20.0		1.4477		
γ-Chlorobutyryl chloride	71.0-71.2	20.0		1.4597		
Ethyl α-chlorobutyrate	64.2-64.4[3]	20.0		1.4202		
Ethyl β-chlorobutyrate	69.9-70.1[3]	20.0		1.4222		
n-Propyl acetate	101-102	745		1.3823		
1-Chloropropyl acetate	48.6-48.8	20.0		1.4143		
2-Chloropropyl acetate	57.1-57.6	20.0		1.4205		
3-Chloropropyl acetate	58.4-58.8	10.0		1.4275		
n-Propyl chloroacetate	52.6-52.8	10.0		1.4233		

[1] Chlorine analysis by reaction with sodium diphenyl in dimethyl "Cellosolve" [L. M. Liggett, Anal. Chem., 26, 748(1954)].

[2] Av. of three analyses (56.17, 56.22 and 56.25%).

[3] Uncorrected.

Table 3.11: Chlorinated Hydrocarbons *(13)*

Carbon Tetrachloride	1.589*	13.22*	170	172	6.00	90.0	—	—	—	0.080*	0.013*	1.4598
1,1,1, Trichloroethane	1.319*	10.97*	162	190	6.00	100.0	—	—	—	—	—	1.4350*
Chloroform Tech	1.478*	12.31*	142		11.60	160.0	—	—	—	0.800*	0.097	1.4455
Ethylene Dichloride	1.252*	10.42*	179	186	4.46	61.6	59CC	—	—	0.810	0.150	1.4427
Methylene Chloride	1.320*	10.98*	103	104	14.50	350.0	—	—	—	1.320*	0.198*	1.4210
Monochlorobenzene	1.105*	9.19*	267	270	1.07	8.8	105	—	—	0.048	Insoluble	1.5215
Orthodichlorobenzene	1.303*	10.84*	355	362	0.15	62.0*	155	—	—	0.014	Insoluble	1.5482
Perchloroethylene	1.618*	13.46*	250	254	2.10	14.0	—	—	—	0.015*	0.010*	1.5044
Propylene Dichloride	1.159*	9.64*	204	208	3.22	43.0	63CC	—	—	—	—	1.4371*
Trichlorobenzene	1.454*	12.10*	418	427	0.06	22.0*	260	—	—	—	—	1.5690*
Trichloroethylene	1.459*	12.14*	188	190	4.46	59.0	—	—	—	0.110*	0.032*	1.4780
	*Detd. at 25°C	*Detd. at 25°C				*Detd. at 100°C				*Detd at 25/20°C	*Detd. at 25/20°C	*Detd. at 25/20°C

Table 3.12: Chlorinated Organic Solvents *(69)*

	Specific Gravity 20°/20° C	Dist. Range °F IBP	Dist. Range °F DP	Flash Pt. °F TOC
Carbon Tetrachloride	1.584	169	171	None
Chloroform	1.485	140	143	None
Ethylene Dichloride	1.255	181	183	70
Methylene Chloride	1.366	103	105	None
Monochlorobenzene	1.113	268	271	84*
Orthodichlorobenzene	1.313	355	361	170
Perchlorethylene	1.627	247	251	None
Trichlorethylene	1.455	187	190	None
1,1,1-Trichloroethane	1.316	162	190	None

*TCC

Table 3.13: CHLOROWAX Liquid Chlorinated Paraffins, Waxes, and Alpha Olefins *(27)*

CHLOROWAX Liquid Grades	SP.GR. @25°C	STOKES @25°C	POISE @25°C	SUS 210°F	SUS* 100°F	Color Max.	Water % Max.	Wt.%Cl_2	JQD Wt.%HCl	HCl ppm	Mol. Wt.
LV	1.110-1.128	5.4-9.0	6.0-10.0	50-100	1,350	4	0.1	35.0-39.5	0.50 max	10	545
100	1.113-1.131	1.8-2.6	2.0-3.0	50-60	450	4	0.1	39.2-41.0	0.50 max	10	454.5
40	1.16-1.185	19-27	22-32	120-160	4,000	4	0.1	41.0-44.5	0.50 max	10	579.5
41SW	1.60-1.175	14-28	16-33	115-145	3,200	5	0.1	41-43	0.50 max	15	579.5
42-170	1.170-1.180	28-37	32-44	150-185	5,200	8	0.1	41-42.5	0.50 max	10	578.5
45-225	1.210-1.23	55-90	66-111	205-245	11,000	8	0.1	45-46.5	0.50 max	10	596
45LV	1.08-1.115	.10-.20	.11-.22	33	58	2	0.1	40-44	0.25 max	10	273.5
S-45	1.155-1.175	1.3-1.9	1.5-2.2	45-52	NA	2	0.1	43-45	0.25 max	10	360
S-52	1.255-1.267	9-15	11-20.	63-80	NA	2	0.1	51.5-52.5	0.25 max	10	440
50	1.22-1.24	70-135	85-168	235-300	10,000-16,000	4	0.1	46-50	0.50 max	10	648.5
50LV	1.196-1.224	.55-.90	.66-1.1	39-41	135-190	2	0.1	49-51	0.25 max	10	334
51-225	1.270-1.285	95-150	120-195	200-240	10,000-14,000	8	0.1	50.0-51.5	0.50 max	10	558
50-410HV	1.266-1.272	NA	NA	550-610	NA	8	0.1	49-53	0.50 max	10	648.5
57-60	1.31-1.33	12-20	16-27	55-70	1,500-2,000	4	0.1	55-58.5	0.25 max	5	391
500C**	1.345-1.375	12.-18	17-25	55-68	1,500-2,100	2	0.1	58.3-60.0	0.25 max	5	377.7
60-70	1.374-1.390	26-40	36-55	65-80	2,700-3,700	4	0.1	60.2-60.7	0.25 max	10	411.5
63-85	1.40-1.42	38-66	53-94	75-92	3,700-5,500	4	0.1	61.5-63.3	0.25 max	10	446
70-200	1.45-1.51	NA	NA	180-230	48,000-61,000	4	0.1	63-66	0.50 max	10	511
53-45	1.28-1.31	4-8	5.5-12	44-56	700-850	2	0.1	53-56	0.50 max	10	342
60-350	1.395-1.42	NA	NA	300-350	NA	4	0.1	59-62	0.50 max	10	600
65	1.445-1.465	150-320	220-470	100-140	17,500-24,000	4	0.1	64-65	0.25 max	10	446
CHLOROWAX Alpha Olefins											
100AO	1.100-1.133	2.0-2.6	2.2-2.9	58-70	500	2	0.1	38-40.5	0.25 max	5	475
45AO	1.090-1.120	.13-.20	.14-.23	NA	NA	2	0.1	40-43	0.25 max	10	273.5
500AO	1.345-1.370	12.-24	16-33	64-78	2,000-2,400	2	0.1	57-60	0.25 max	5	377
54-120AO	1.285-1.325	31-68	40-90	105-135	4,500-6,500	2	0.1	53-55	0.25 max	5	467
52AO	1.240-1.270	1.4-2.7	1.7-3.4	40-50	275	2	0.1	51.0-53.5	0.25 max	5	342
51-225AO	1.27-1.285	95-150	120-195	200-250	NA	4	0.1	50-52	0.50 max	4	558

(continued)

Table 3.13: (continued)

Compatibility of Liquid Chlorowax with Other Materials

Alkyd Resins	
Phthalic-Drying Oil Modified	Solution
Phthalic-Non-Drying Oil Modified	Solution
Resin Modified	Solution
Styrene Modified	Solution
Rosin Modified	Solution
Asphalt, Petroleum	Hot Melt
Butyl Oleate	Hot Melt
Carbowax	Hot Melt
Cellulose Acetate	Hot Melt
Cellulose Acetate Butyrate	Solution
Chlorinated Rubber	Solution
Coumarone-Indene Resins	Solution
Dibenzyl Sebacate	Solution
Dibutyl Phthalate	Solution
Dicapryl Phthalate	Solution
Di-iso-butyl Adipate	Solution
Dioctyl Adipate	Solution
Dioctyl Phthalate	Solution
Di-iso-octyl Phthalate	Solution
Diocytl Sebacate	Solution
Epoxy Resins	Solution
Maleic Resins	Solution
Methyl Methacrylate	Solution
Petroleum Resins	Solution
Paraplex G-60	Solution
Paraplex G-62	Solution
Phenolic Resin, Non-heat Hardening	Solution
Pliolite Resins	Solution
Polydichlorstyrene	Solution
Polyester Resins	Solution
Polyethylene Resins	Solution
Polystyrene Resins	Solution
Polyvinyl Chloride Resins	Solution
Rosin	Solution
Rosin Ester Resins	Solution
Rubber	
Natural	Solution
Nitrile	Solution
SBR	Solution
Neoprene	Solution
Butyl	Solution
Santicizer 141	Solution
Santicizer 160	Solution
Terpene Resins	Solution
Tetrahydrofurfural Oleate	Solution
Triaryl Phosphate	Solution
Tricresyl Phosphate	Solution
Triphenyl Phosphate	Solution
Urea Formaldehyde Resins	Solution
Waxes	
Mineral	Hot Melt
Natural	Hot Melt
Paraffin	Hot Melt

(continued)

Table 3.13: (continued)

Miscibility of OxyChem Chlorowax Grade

CHLOROWAX is miscible with many organic solvents, including aliphatic, aromatic and terpene hydrocarbons; chlorinated aliphatic and aromatic hydrocarbons; hydrogenated naphthas; ketones, esters and drying oils. They are insoluble in water, glycerine and glycols. With a few exceptions, the liquid grades are insoluble in the lower alcohols.

SOLVENT	MISCIBLE WITH	
	CHLOROWAX 45LV, 500-C, 50 LV & 65	OTHER GRADES
Acetone	Yes	Yes
Amyl Acetate	Yes	Yes
Benzene	Yes	Yes
Butanol, Normal	Yes	No
Butanol, Tertiary	Yes	No
Carbon Tetrachloride	Yes	Yes
Dioxane	Yes	Yes
Ethanol	Yes	No
Ethylene Acetate	Yes	Yes
Ethylene Dichloride	Yes	Yes
Ethylene Glycol	No	No
Glycerine	No	No
Isopropanol	No	No
Linseed Oil	Yes	Yes
Methanol	Yes	No
Methyl Ethyl Ketone	Yes	Yes
Methylene Chloride	Yes	Yes
Mineral Spirits	Yes	Yes
Monochlorobenzene	Yes	Yes
Orthodichlorobenzene	Yes	Yes
Perchloroethylene	Yes	Yes
Perilla Oil	Yes	Yes
Propanol	Yes	No
Solvesso 100	Yes	Yes
Soy Bean Oil	Yes	Yes
Toluene	Yes	Yes
Turpentine	Yes	Yes
Xylene	Yes	Yes

Table 3.14: Chlorobenzenes—Vapor Pressures *(72)*

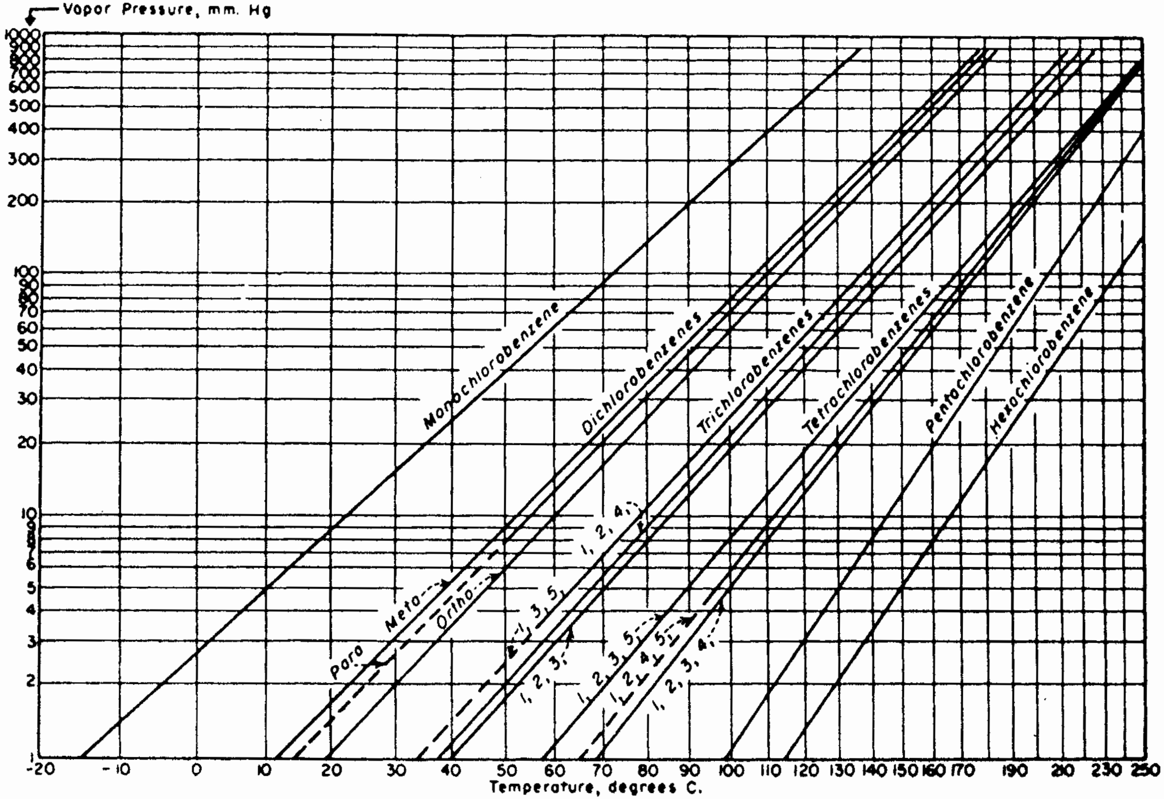


Table 3.15: Chloroform *(7)*

Trichloromethane $CHCl_3$

PHYSICAL PROPERTIES

Acidity as HCl	0.001% by wt, max.
Boiling point	61.2°C
Boiling range @760 mm	60.0-61.5°C
Coefficient of cubical expansion Av./°C, liquid	0.001399
Color (Saybolt)	24 max.
Dielectric constant, 1000 cycle	4.90
Fire point	Nonflammable
Flash point	Nonflammable
Freezing point	63°C
Heat of evaporation @B.P.	59.0 cal/g
Latent heat of evaporation @B.P.	106.4 Btu/lb
Refractive index @20°C	1.4467
@25°C	1.4422
Solubility in water @20°C	0.82
Solubility of water in solvent @10°C	0.06 g/water/100 g
Specific gravity 25/25°C	1.477
Specific heat Liquid, 20°	0.234 cal/g/°C
Specific resistivity	4.0×10^9 ohms/cm
Thermal conductivity Liquid	0.080 Btu/hr (sq ft) (°F/ft)
Vapor density (B.P., 760 mm)	4.36 g/liter
Vapor pressure @30°C	243 mm
Viscosity @20°C	5.63 millipoises
@30°C	5.10 millipoises
Water: no cloud @-10°C	0.021% by wt, max.
Weight per gallon @25°C	12.29 lb

CHLOROFORM FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
20.5	Acetone	64.5
35	2-Bromopropane	62.2
96	2-Butanone	79.7
6.8	Ethanol	59.3
13	Ethyl formate	62.7
15	Formic acid	59.2
2.8	n-Hexane	60
4.5	Isopropanol	60.8
12.5	Methanol	53.5
23	Methyl acetate	64.8
2.8	Water	56.1

Table 3.16: Chloromethylene Compounds *(24)*

PRODUCT	EMPIRICAL FORMULA	MOL. WT.	PHYSICAL CONSTANTS: BOILING RANGE °C	PHYSICAL CONSTANTS: SPECIFIC GRAVITY 25°/25°C.	PHYSICAL CONSTANTS: REF. INDEX n^{25}_D	ASSAY (Method)	ISOMER CONTENT (Prox.)
COMMERCIAL							
BENZYL CHLORIDE	C_7H_7Cl	126.6	95% in 3° range incl. 179°C	1.040–1.111	1.5360–1.5370	99% min. (1)	––
para-METHYLBENZYL CHLORIDE	C_8H_9Cl	140.6	199–204°	––	1.535–1.540	98% (1)	––
METHYLBENZYL CHLORIDES	C_8H_9Cl	140.6	199–204°	1.070–1.080 (15.5°)	1.5360–1.5370	98% (2)	55% (p-) 45% (o-)
ETHYLBENZYL CHLORIDES	$C_9H_{11}Cl$	154.7	217–222°	1.046–1.047	1.5293–1.5305	99% (2)	70% (p-) 30% (o-)
ISOPROPYLBENZYL CHLORIDES	$C_{10}H_{13}Cl$	168.7	109–112° @ 15mm.	1.01–1.03	1.520–1.530	98.5% (1)	85% (p-) 15% (o-)
2,4-DIMETHYLBENZYL CHLORIDES	$C_9H_{11}Cl$	154.7	221–226°	1.050–1.065	1.5375–1.5385	98.5% (2)	86% (2,4-) 14% (2,6-)
3,4-DIMETHYLBENZYL CHLORIDES	$C_9H_{11}Cl$	154.7	225–232°	1.059–1.062	1.5370–1.5390	99% (2)	64% (3,4-) 34% (2,3-) 2% (2,4-; 2,5-; 2,6-)
DICHLOROBENZYL CHLORIDES	$C_7H_5Cl_3$	195.5	245–253°	1.410–1.418	1.5755–1.5765	94% (2)	80% (2,4-; 2,5-; 2,6-) 20% other isomers
DEVELOPMENT							
2,5-DIMETHYLBENZYL CHLORIDE	$C_9H_{11}Cl$	154.7	221–226°	1.035–1.045	1.5350–1.5360	98% (2)	––
meta-CHLOROBENZYL CHLORIDE	$C_7H_6Cl_2$	161.1	98–104° @ 15mm.	1.25–1.27	1.5532–1.5542	97.5% (1)	––
α,α′-DICHLORO-XYLENES	$C_8H_8Cl_2$	175.1	prox.133°C @ 15mm.	––	––	95% (1)	70-80% (p-) 20-30% (o-)
Bis-CHLOROMETHYL-DURENE	$C_{12}H_{16}Cl_2$	231.2	190–196° dec. (3)	––	––	98% (2)	––
RESEARCH							
ortho-METHYLBENZYL CHLORIDE	C_8H_9Cl	140.6	––	––	––	98% (1)	––
meta-METHYLBENZYL CHLORIDE	C_8H_9Cl	140.6	––	––	––	98%	––
CHLOROMETHYL-TETRALINS	$C_{11}H_{13}Cl$	180.5	135–145° @7mm.	––	––	98% (2)	60% (β-) 40% (α-)
α-CHLOROMETHYL-β-METHYLNAPHTHALENE	$C_{12}H_{11}Cl$	190.7	58–62° (3)	––	––	95% min. (2)	––

(1) Gas-Liquid Partition Chromatography
(2) Alcoholic potassium hydroxide hydrolysis
(3) Melting range

Table 3.17: o- and p-Chlorotoluenes *(7)*

$C_6H_4(Cl)CH_3$

PHYSICAL PROPERTIES

	Ortho	Para
Boiling point	159.4°C	162.5°C
Coefficient of cubical expansion @30°C	0.00092	
Distillation range		
Start	158.3°C min.	
100%	165.1°C max.	
Flash point	46°C	
Freezing point	-34°C	7.5°C
Latent heat of vaporization	77 cal/g	
Purity	60% approx.	40% approx.
Solubility of water @25°C	0.037 g/100 g	
Solubility of water in solvent @25°C	0.014 g/100 g	
Refractive index @20°C	1.5238	1.5199
Specific gravity @20/4°C	1.0817	1.0697
Surface tension @25°C	32.9 dynes/cm	
Vapor pressure @100°C	132 mm	
Viscosity @100°F	0.707 centistoke 0.747 centipoise	
@210°F	0.328 centistoke 0.327 centipoise	
Weight per gallon @25°C	9.1 lb	

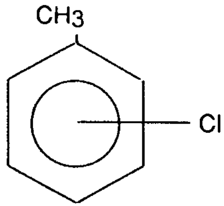
Table 3.18: p-Chlorotoluene *(7)*

$C_6H_4(Cl)CH_3$

PHYSICAL PROPERTIES

Acidity as acetic acid	Nil
Boiling point @760 mm Hg	162.3°C
@50 mm Hg	78.4°C
@10 mm Hg	43.8°C
Congealing point	6.8°C
Distillation range @760 mm Hg	162-166°C
Flash point (Cleveland O.C.)	140°F
Moisture content	Nil
Molecular weight	126.59
Pounds per gallon	8.85
Purity	98.0%
Refractive index N_{22}^{D}	1.5184
Side chain chlorine	None
Solidifies	Below 45°F
Specific gravity @25/25°C	1.067 min. - 1.071 max.
Surface tension (in air) DuNouy @25°C	34.60 dynes/cm
Vapor pressure @96.6°C	100 mm Hg

Table 3.19: HALSO 99 *(27)*



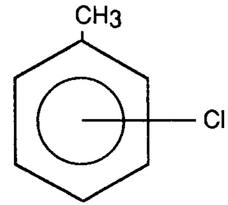
Specifications:

Appearance	Clear liquid
Color	30 APHA Max.
Monochlorotoluene	99.6% Min.
Toluene	0.4% Max.

Physical Properties:

	Monochlorotoluene		
	Ortho	Para	Toluene
Formula	C_7H_7Cl		C_7H_8
Molecular Weight	126.59		92.14
CAS Registry Number	95-49-8	106-43-4	108-88-3
Specific Gravity @ 25°C/15.5°C	1.079	1.067	0.863
Specific Gravity Correction Factor	-0.00088/°C	-0.00097/°C	-
Density (lb/gal)	9.0	8.9	7.2
Freeze Point, °C (°F)	-35.6 (-32)	7.5 (45.5)	-95 (-139)
Boiling Point, °C (°F)	159 (318)	162 (324)	111 (231)
Flash Point (TCC), °C (°F)	50.6 (123)	52.8 (127)	4.4 (40)
Fire Point (COC), °C (°F)	85 (185)	87.7 (190)	-
Vapor Pressure, 10 mm Hg	43.2°C	43.8°C	6.4°C
100 mm Hg	94.7°C	96.6°C	51.9°C
760 mm Hg	159.2°C	161.7°C	110.6°C
Refractive Index (n_D 20)	1.5268	1.5150	1.4961
Heat of Vaporization (cal/gm)	81.2	80.2	93.1
Specific Heat @ 20°C (cal/gm/°C)	0.355	0.355	0.392
Viscosity (Centistokes) @ 100°F	0.75	-	-
@ 210°F	0.44	-	-
Kauri-Butanol Value	110		105
Solubility in Water @ 23°C (ppm)	72	74	-

Table 3.20: HALSO AG 125 *(27)*



Specifications:

Appearance	Clear liquid
Color	25 APHA Max.
Monochlorotoluene	99.5% Min.
Toluene	0.4% Max.

Physical Properties:

	Monochlorotoluene		
	Ortho	Para	Toluene
Formula	C_7H_7Cl		C_7H_8
Molecular Weight	126.59		92.14
CAS Registry Number	95-49-8	106-43-4	108-88-3
Specific Gravity @ 25°C/15.5°C	1.079	1.067	0.863
Specific Gravity Correction Factor	-0.00088/°C	-0.00097/°C	-
Density (lb/gal)	9.0	8.9	7.2
Freeze Point, °C (°F)	-35.6 (-32)	7.5 (45.5)	-95 (-139)
Boiling Point, °C (°F)	159 (318)	162 (324)	111 (231)
Flash Point (TCC), °C (°F)	50.6 (123)	52.8 (127)	4.4 (40)
Fire Point (COC), °C (°F)	85 (185)	87.7 (190)	-
Vapor Pressure, 10 mm Hg	43.2°C	43.8°C	6.4°C
100 mm Hg	94.7°C	96.6°C	51.9°C
760 mm Hg	159.2°C	161.7°C	110.6°C
Refractive Index (n_D 20)	1.5268	1.5150	1.4961
Heat of Vaporization (cal/gm)	81.2	80.2	93.1
Specific Heat @ 20°C (cal/gm/°C)	0.355	0.355	0.392
Viscosity (Centistokes) @ 100°F	0.75	-	-
@ 210°F	0.44	-	-
Kauri-Butanol Value	110		105
Solubility in Water @ 23°C (ppm)	72	74	-

Table 3.21: o-Dichlorobenzene *(7)*

1,2-Dichlorobenzene $C_6H_4{-}Cl_2$

PHYSICAL PROPERTIES

	Purified	Technical
Boiling point	180.2°C	179.6°C
Boiling range (within)	3.0°C	4.0°C
Dielectric constant 1000 cycles	9.82	
Electrical conductivity @0°C	10^{-9} recip. ohm	
Fire point	103°C	103°C
Flash point	68°C	68°C
Freezing point	-18.3°C	-22.5°C
Heat of combustion	671.8 kg cal/mol.	
Heat of fusion	88 joules/g	
Impurities (p-dichlorobenzene, trichlorobenzene)	Not over 4%	Not over 12%
Latent heat of vaporization @B.P.		65 cal/g at.
Refractive index @22°C		1.5518
Solubility in water @25°C		Less than 0.01%
Specific gravity @20/4°C		1.3048
Specific heat		0.271 cal/g/°C
Specific resistivity		2.0 x 10^8 ohms/cm
Weight per gallon @25°C		10.85 lb

Table 3.22: p-Dichlorobenzene *(7)*

p-DICHLOROBENZENE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
20	Cineole	173.5
33.5	Cyclohexanol	153.6
37	2-Ethoxyethyl acetate	155.5
34	n-Hexyl alcohol	151.6
46	Camphene	155.0
63.5	Isoamyl ether	172.4
27	Isoamyl propionate	155.2
14	d-Limonene	174.2
50	α-Pinene	153.4
2	Phenol	156.0
43	Propyl isovalerate	154.5

Table 3.23: Dichlorodiisopropyl Ether *(7)*

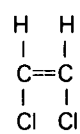
$ClCH_2CH(CH_3)\text{-}O\text{-}CH(CH_3)CH_2Cl$

PHYSICAL PROPERTIES

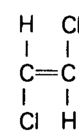
Acidity as HCl	0.01% by wt, max.
Boiling point @760 mm	187.3°C
Boiling range @760 mm	Not more than 5% distills below 180°C Not less than 95% distills below 190°C
Color (Pt-Co scale)	25 max.
Flash point (O.C.)	185°F
Solubility in water @20°C	0.17% by wt
Solubility of water in solvent @20°C	0.11% by wt
Specific gravity @20/20°C	1.1122
Vapor pressure @20°C	0.85 mm
Weight per gallon @20°C	9.26 lb

Table 3.24: Dichloroethylene *(7)*

cis-Acetylene Dichloride



trans-Acetylene Dichloride



PHYSICAL PROPERTIES

cis isomer

Acidity as HCl	0.0005% by wt, max.
Boiling point @760 mm	60.3°C
Coefficient of cubical expansion Av./°C, liquid	0.00127
Color (Saybolt)	24 max.
Flash point	6°C
Freezing point	-80.5°C
Latent heat of vaporization @B.P.	73.0 cal/g
Refractive index @15°C	1.4519
Residue on evaporation	0.007% by wt, max.
Solubility in water @25°C	0.77 g/100 g
Solubility of water in solvent @10°C	0.04 g water/100 g
Specific gravity @20/4°C	1.282
Specific heat Liquid, 20°C	0.270 cal/g/°C
Vapor density (B.P., 760 mm)	3.54 g/liter
Vapor pressure @30°C	273 mm
Viscosity liquid @20°C	0.48 centipoise
Water: no cloud @-15°C	0.001% by wt, max.
Weight per gallon @20°C	10.70 lb

PHYSICAL PROPERTIES

trans isomer

Acidity as HCl	0.0005% by wt, max.
Boiling point @760 mm	48.0-48.5°C
Boiling range @760 mm	47.0-48.5°C
Coefficient of cubical expansion Av./°C, liquid	0.00136
Color (Saybolt)	24 max.
Flash point	4°C
Freezing point	50°C
Latent heat of vaporization @B.P.	73.7 cal/g
Refractive index @15°C	1.4490
Residue on evaporation	0.0007% by wt, max.
Solubility in water @25°C	0.63 g/100 g
Solubility of water in solvent @10°C	0.03 g water/100 g
Specific gravity @20/4°C	1.257
Specific heat Liquid, 20°C	0.270 cal/g/°C
Vapor density (B.P., 760 mm)	3.67 g/liter
Vapor pressure @30°C	395 mm
Viscosity liquid @20°C	0.41 centipoise
Water: no cloud @-15°C	0.004% by wt, max.
Weight per gallon @20°C	10.49 lb

Table 3.25: Dichloroethyl Ether *(7)*

2,2'-Dichloroethyl Ether
sym- or β,β'-Dichloroethyl Ether

$ClCH_2CH_2OCH_2CH_2Cl$

PHYSICAL PROPERTIES

Acidity as HCl	0.005% max.
Apparent ignition temperature in air	396°C
Boiling point	178°C
Boiling range @760 mm	Not more than 5% distills below 173°C Not less than 95% distills below 179°C
Color (500 mm tube)	Not more than 2 yellow Lovibond
Ethylene dichloride	1.0% max.
Flash point (C.C.)	55°C
Latent heat of vaporization @178°C	64.1 cal/g
Refractive index @20°C	1.457
Specific gravity @20/20°C	1.219-1.224
Specific heat @20-30°C	0.369 cal
Surface tension @25°C	41.8 dynes/sq cm
Vapor pressure @20°C	1.2 mm
Viscosity @25°C	2.0653 centipoises
Weight per gallon @20°C	10.17 lb

Table 3.26: Dichlorohydrin *(7)*

Glycerol Dichlorohydrin
Dichloroisopropyl Alcohol
1,3-Dichloropropanol-2
α-Propenyldichlorohydrin

$ClCH_2CH(OH)CH_2Cl$

PHYSICAL PROPERTIES

Boiling point	(1,3-) 174°C (1,2-) 183°C
Boiling range	174-176°C (95%)
Flash point	74°C
Refractive index	1.47-1.48
Specific gravity	1.36-1.39
Vapor pressure	7 mm

1,2-DICHLORO-3-PROPANOL FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
55	o-Bromotoluene	171.6
75	Camphene	156.0
60	α-Chlorotoluene	171.0
68	Indene	160.0
60	α-Limonene	169.3
43	2-Octanol	172.5
80	α-Pinene	153.0
50	Thymene	170.8

1,3-DICHLORO-2-PROPANOL FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
91	Bromobenzene	155.5
39	o-Bromotoluene	170.5
32	p-Bromotoluene	172.8
62	Camphene	152.8
43	α-Chlorotoluene	168.9
85	o-Chlorotolene	158.0
78	p-Chlorotoluene	160.0
45	Cymene	165.5
55	p-Dichlorobenzene	162.2
62	2,7-Dimethyllactane	155.0
85	Dimethyl oxalate	162.0
33.5	Indene	173.5
30	Iodobenzene	173.0
10	Isoamyl butyrate	178.6
52	Isoamyl ether	165.9
43	d-Limonene	166.8
50	Mesitylene	156.0
41	p-Methylanisole	173.1
35	Methylheptenone	178.5
57	α-Phellandrene	163.0
63.5	α-Pinene	150.4
63	Pseudocumene	164.4
85	Styrene	142.5
38	α-Terpinolene	166.8
40	Thymene	166.5

Table 3.27: Dichloromethane *(22)*

Methylene Chloride
Methylene Dichloride

CH_2Cl_2

Methylene chloride is a clear, water-white liquid at ordinary temperatures, with a pleasant, ethereal odor. It is highly volatile and mobile. Methylene chloride is completely miscible with most organic liquids.

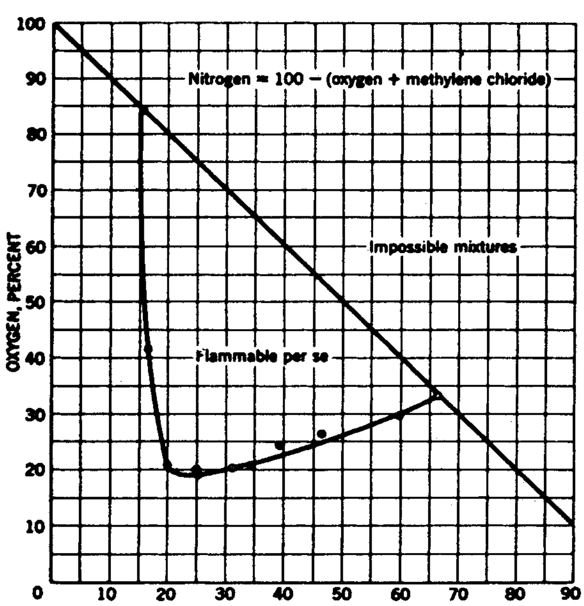
TYPICAL PROPERTIES

Molecular Weight	84.93
Boiling Point, °F	103.6
°C	39.8
Freezing Point, °F	– 142.1
°C	– 96.7
Flash Point (Tag open cup)	none
Ignition Temperature, °F	1224
°C	662
Specific Gravity of Vapor (air = 1.00)	2.94
Density at 20°C, pounds per gallon	11.15
Viscosity at 20°C, centipoises	0.425
Specific Heat at 20°C, cal/(g)(°C)	0.29
Vapor Pressure at 20°C, mm	348.9
Evaporation Rate at 25°C (ether = 100)	71
Heat of Vaporization, cal/g	75.3
Btu/lb	135.5
Solubility g methylene chloride/100 g water at 20°C	2.0
g water/100 g methylene chloride at 25°C	0.2
Azeotrope with Water, Boiling Point, °F	100.6
°C	38.1
Azeotropic Water Content, wt %	1.5

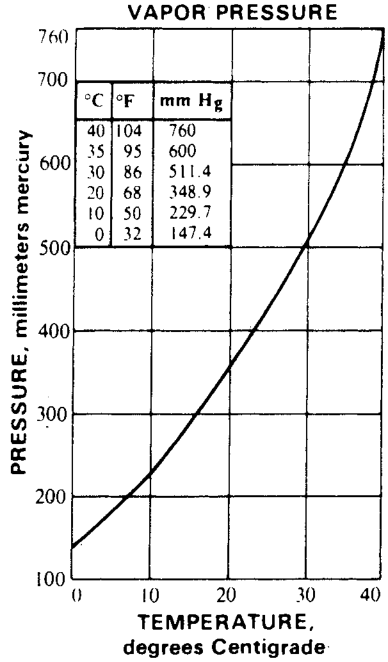
Specification for standard grade

Appearance	Clear, free of suspended matter
Color, APHA, maximum	10
Odor	Characteristic; no residual
Specific Gravity, 25°C/25°C	1.319 to 1.323
Acidity, ppm, maximum	5
Nonvolatile Residue, ppm, maximum	10
Free Halogen	none
Distillation Range (100%), °C	39.5 to 40.5
°F	103.1 to 104.9
Water, ppm, maximum	100

Flammability of Methylene Chloride-Oxygen-Nitrogen Mixtures



VAPOR PRESSURE



(continued)

Table 3.27: (continued)

1,1-DICHLOROMETHANE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
30	Acetone	57.6
23	Biallyl	56.5
94.8	1,3-Butadiene	-5.0
20	Chloromethyl methyl ether	54
30	Cyclopentane	38.0
55	Diethylamine	52.0
11.5	Ethanol	54.6
21	Iodomethane	39.8
8	Isopropanol	56.6
51	Pentane	35.5
23	Propylene oxide	40.6
6	tert-Butanol	57.1
1.5	Water	38.1

Table 3.28: Dichloropentanes *(7)*

$C_5H_{10}Cl_2$

PHYSICAL PROPERTIES

Acidity as HCl	0.025% max.
Average chlorine content	48%
Distillation	95% between 130-200°C
Evaporation rate @109°F: Minutes	
3.83	25%
8.00	50%
14.20	75%
90.00	100%
Flash point (O.C.)	97°F
Heat of vaporization	68.5 cal/g
Kauri-butanol value	67 cc
Solubility in water	Negligible
Specific gravity @20°C	1.07-1.08
Specific heat	0.369 cal/g
Surface tension @25°C	31.8 dynes/cm
Viscosity @25°C	0.016 poise
Water azeotrope @80-97°C	66% $C_5H_{10}Cl_2$ (approx.)
Water content	None
Weight per gallon	8.94 lb

Table 3.29: 2,4-Dichlorotoluene *(7)*

$C_6H_3(Cl)_2CH_3$

PHYSICAL PROPERTIES

Acidity as acetic acid	Nil
Boiling point @760 mm Hg	200.5°C
@50 mm Hg	113.0°C
@10 mm Hg	77.0°C
Congealing point	-13°C
Distillation Range @760 mm Hg	199-202°C
Fire point (Cleveland O.C.)	383°F
Flash point (Cleveland O.C.)	199°F
Moisture content	Nil
Molecular weight	161.04
Pounds per gallon	10.34
Purity	99.0%
Refractive index N_{22}^{D}	1.5480
Side chain chlorine	None
Specific gravity @25/25°C	1.247 min.-1.251 max.
Surface tension, DuNouy @25°C	38.29 dynes/cm
Vapor pressure @130°C	100 mm Hg

Table 3.30: Epichlorohydrin *(7)*

3-Chloropropylene-1,2-oxide $O{-}CH_2{-}CH{-}CH_2Cl$ (O and CH joined by a bond)

Epichlorohydrin is a colorless, mobile, highly reactive liquid. It is completely miscible with many organic liquids such as acetone, carbon tetrachloride, alcohols, benzene, ethers, halogenated hydrocarbons, fixed oils, etc. It is not miscible with glycerin and water. The two reactive functional groups make it a very useful chemical intermediate. In the presence of a catalyst, its epoxy group enters into an exothermic reaction with the active hydrogen atoms of alcohols, amines, carboxylic acids, phenols, mercaptans, etc. The atom in the molecule reacts with acid salts, alkali metal phenolates, and alcoholates, amides, amines, etc.

Epichlorohydrin is used to a large extent as a raw material in the manufacture of epoxy resins. When condensed with dihydric phenols or phenolic resins, epoxy resins are obtained which range from liquids to solids. It is also used in the manufacture of ion exchange resins, adhesion resins and a large number of other chemicals.

Absolute viscosity at 20°C., cps.	1.1
ΔBP/ΔP., at 740 to 760 mm. Hg, °C. per mm.	0.044
Boiling point, °C., 760 mm.	115.2
50 mm.	45
10 mm.	16
Freezing point, °C.	-58.1
Heat of vaporization at 1 atm., Btu/lb.	174
Molecular weight	92.53
Refractive index, n_D at 20°C.	1.4359
Solubility, % by weight at 20°C.,	
in water	5.9
water in	1.2
ΔSG/ΔT. at 20° to 30°C.	0.00120
Specific gravity at 20/20°C.	1.1761
Vapor pressure at 20°C., mm. Hg	12.7
Flash point (open cup), °F.	105

Table 3.31: Ethyl Chloride *(22) (23)*

Monochloroethane C_2H_5Cl
Muriatic Ether

TYPICAL PROPERTIES

Molecular Weight: 64.52

Description: Ethyl chloride is a colorless mobile liquid at 1 atmosphere below 12.4°C (54°F). Above the boiling point, it is a colorless gas. Ethyl chloride has an ethereal odor and is highly volatile and flammable.

Freezing Point, °C	−138.3
°F	−217
Refractive Index of Vapor, n_D^{25}	1.001
Vapor Pressure, mm Hg	
0°C (32°F)	464
10°C (50°F)	692
20°C (68°F)	1011
Specific Gravity of Vapor (air=1)	2.23
Solubility at 0°C,	
g ethyl chloride/100 g water	0.447
g water/100 g ethyl chloride	0.07

Solubility:
Ethyl chloride is soluble in most organic solvents.

(continued)

Table 3.31: (continued)

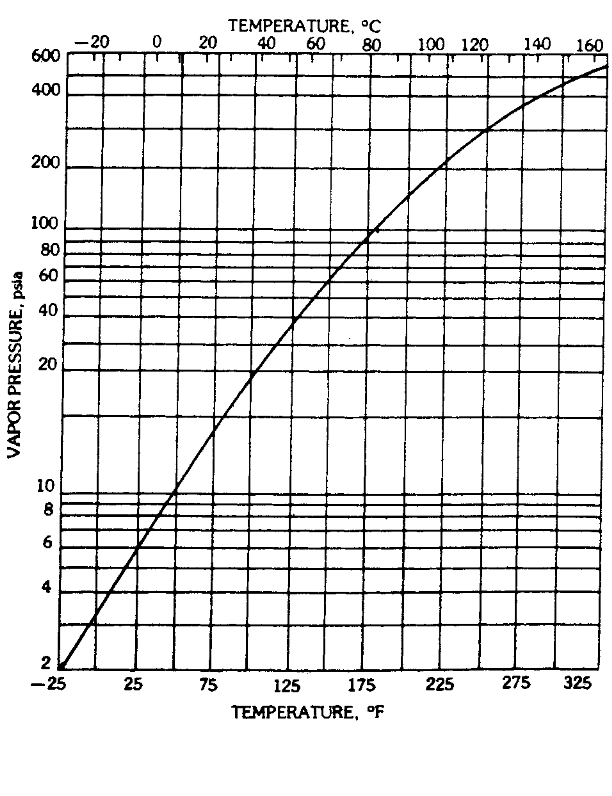
Flash Point, Tag open cup, °C	−43
°F	−45
Explosive Limits, volume % in air	3.16 to 15
Autoignition Temperature, °C	519
°F	966
Specific Heat at 0°C, cal/ (g) (°C) or Btu/ (lb) (°F)	0.37
Heat of Vaporization at Boiling Point	
cal/g	92.5
Btu/lb	165.6
Viscosity at 10°C, cps	0.279
Density at 20°C, pounds/gallon	7.461

Reactivity:
At ordinary temperatures the oxidation and hydrolysis of ethyl chloride take place slowly. In the absence of air and water, it can be used with most common metals up to 200°C (392°F). Ethyl chloride burns with a green-edged flame, producing hydrogen chloride, carbon dioxide and water. It is thermally stable to 400°C (752°F); thermal splitting yields ethylene and hydrogen chloride. The reactivity of ethyl chloride as an intermediate is often based on the affinity of alkali metal atoms for its chlorine atom.

Specification and Typical Analysis:

	Specification	Typical Analysis
Purity, wt %	99.5 minimum	99.97
Color, APHA	20 maximum	<5
Appearance	clear, free of suspended matter	clear, free of suspended matter
Acidity as HCl, wt %	0.002 maximum	<0.0001
Water, wt %	0.02 maximum	0.0010
Nonvolatile Residue, wt %	0.01 maximum	<0.0001
Total Impurities, wt %	0.5 maximum	0.03
Distillation Range, °C	12 to 13	12.2 to 12.4
Specific Gravity, 0°C/4°C	0.922 to 0.925	0.922

Ethyl Chloride Vapor Pressure vs Temperature



Solubility, Approximate, g/100 g Solvent at 25°C

Acetone	103
Benzene	110
n-Heptane	87
Ethanol (21°C)	48
Methanol	37
Water (20°C)	0.6

Table 3.32: Ethylene Chlorohydrin *(7)*

Glycol Chlorohydrin — $ClCH_2CH_2OH$
2-Chlorethyl Alcohol

PHYSICAL PROPERTIES

Absolute viscosity @20°C	3.4 centipoises
Apparent specific gravity @20/20°C	1.2040
Boiling point @760 mm Hg @ 50 mm Hg @ 10 mm Hg	128.7°C 60°C 29°C
Coefficient of expansion @55°C	0.00092
Flash point (Cleveland O.C.)	140°F
Freezing point	-62.6°C
Molecular weight	80.52
Pounds per gallon @20°C	10.03
Solubility in water @20°C	Complete
Solubility of water in solvent @20°C	Complete
Vapor pressure @20°C	4.9 mm Hg

Table 3.33: Ethylene Dichloride *(7)*

1,2-Dichloroethane
sym-Dichloroethane
Ethylene Chloride — $ClCH_2{-}CH_2Cl$
Dutch Oil
Elayl Chloride

PHYSICAL PROPERTIES

Acidity as HCl	Not more than 0.001%
Apparent ignition temperature in air	449°C
Boiling point	83.6°C
Boiling range @760 mm	Below 82.5°C none Above 84.0°C none
Coefficient of cubical expansion Av./°C, liquid (10-30°C)	0.00116
Color (500-mm tube) (Lovibond)	Not more than 1.0 yellow
Dielectric constant @20°C	10.5±0.3
Electrical conductivity	3×10^{-8}
Explosive limits in air	6.2-15.9% by vol.
Fire point	28°C
Flash point (ASTM O.C.)	21°C
Freezing point	-35°C
Heat of combustion	2720 cal/g
Latent heat of evaporation @B.P.	77.3 cal/g
Nonvolatile matter	Not more than 0.001 g/100 cc
Purity	Not less than 99.0%
Refractive index	1.4443
Solubility in water @20°C	0.87% by wt
Solubility of water in solvent @20°C	0.16% by wt
Specific gravity @20/20°C	1.2550
Specific heat	0.31 cal/g/°C
Specific resistivity	9.0×10^6 ohms/cm
Surface tension @25°C	37.5 dynes/cm
Thermal conductivity @20°C	0.0038 cal/cm/sec/°C
Vapor density (B.P., 760 mm)	3.88 g/liter
Vapor pressure @20°C @30°C	63 mm 99 mm
Viscosity @25°C	0.0078 poise
Water content	Not more than 0.02%
Weight per gallon @25°C	10.38 lb

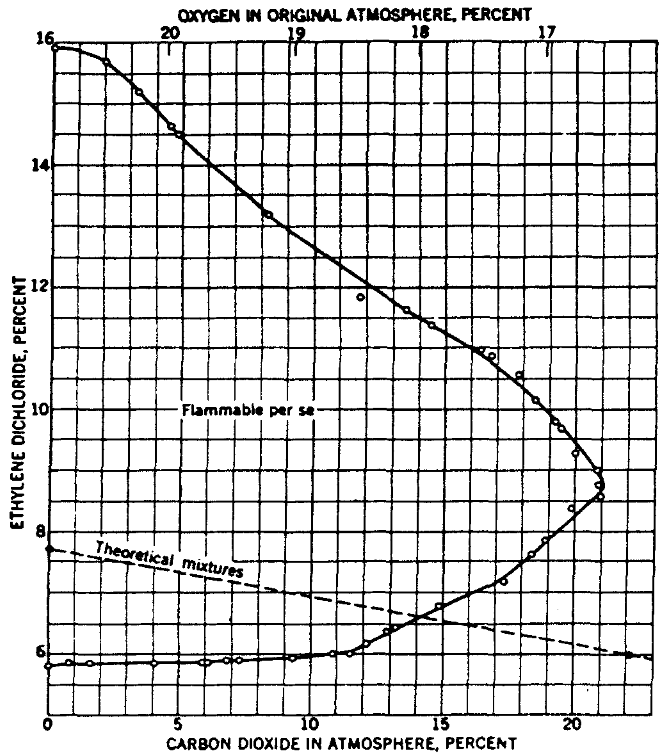
(continued)

Table 3.33: (continued)

ETHYLENE DICHLORIDE FORMS AZEOTROPES WITH:

%		B. P. °C of Azeotrope
18	Allyl alcohol	79.9
6	tert-Amyl alcohol	83
79	Carbon tetrachloride	75.6
19.5	1,1-Dichloroethane	72
37	Ethanol	70.3
38	Formic acid	77.4
6.5	Isobutanol	83.5
43.5	Isopropyl alcohol	74.7
19	Propanol	80.7
10	n-Propyl formate	84.1
18	Trichloroethylene	82.9
32	Methanol	61
8.2	Water	70.5

Limits of Flammability of Ethylene Dichloride in Air and Carbon Dioxide



Water Content vs. Cloud Point *(53)*

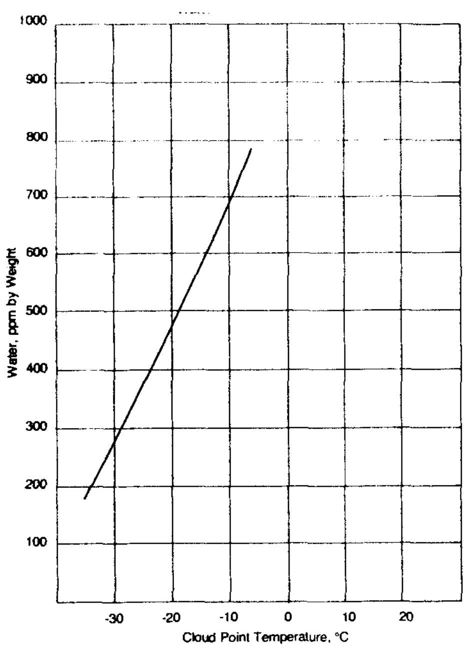


Table 3.34: 2-Ethylhexyl Chloride *(7)*

$CH_3CH_2CH_2CH_2CH(C_2H_5)CH_2Cl$

PHYSICAL PROPERTIES

Average weight @20°C	7.33 lb/gal
Boiling point @760 mm Hg	172.9°C
Flash point (O.C.)	140°F
Molecular weight	148.67
Solubility in water @20°C	0.1% by wt
Solubility of water in solvent @20°C	0.1% by wt
Specific gravity @20/20°C	0.8833
Vapor pressure @20°C	1.3 mm Hg

Table 3.35: Glycerol α-Monochlorohydrin *(7)*

$ClCH_2CHOHCH_2OH$

PHYSICAL PROPERTIES

Boiling point	213°C
Boiling range (ASTM)	90% between 136-142°C @40 mm
Flash point (O.C.)	280°F
Refractive index @25°C	1.4781
Solubility in water	100%
Specific gravity @20/4°C	1.320
Weight per gallon	10.98 lb

Table 3.36: Hexachloroethane *(7)*

Perchloroethane

Carbon Trichloride

Tetrachloroethylene Dichloride

CCl_3CCl_3

PHYSICAL PROPERTIES

Acidity as HCl	Less than 0.05%
Boiling point @760 mm	Sublimes @185°C
Latent heat of vaporization @B.P.	46.4 cal/g 83.5 Btu/lb
Melting point in sealed tube	188.2°C
Nonvolatile matter	Less than 0.15%
Purity	98.0% min.
Specific gravity @20/4°C	2.091
Specific heat @25°C	0.174 cal/g/°C or Btu/lb/°F
Vapor density (B.P., 760 mm)	6.30 g/liter
Vapor pressure @30°C	2 mm
Water	0.2% by wt, max.

HEXACHLOROETHANE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
34	Aniline	176.8
12	Benzyl alcohol	182.0
30	p-Bromotoluene	183.5
25	Chloroacetic acid	171.2
28	o-Cresol	181.3
43	Diethyl oxalate	178.6
20	Diisobutyl carbonate	184.0
55	Dimethyl malonate	176.0
49.5	Ethyl acetoacetate	172.5
37	Isovaleric acid	172.6
30	Phenol	173.7
15	Trichloroacetic acid	181.0

Table 3.37: n-Hexyl Chloride *(7)*

$C_6H_{13}Cl$

Boiling range	**133-135°C**
Flash point	**95°F**
Specific gravity @20/20°C	**0.877**

Table 3.38: Methylene Chloride *(53)*

Product Description

Methylene chloride is a clear, colorless, heavy, nonflammable liquid with a pleasant ethereal odor. It is the least toxic of the chloromethanes and is not photochemically reactive. As one of the most powerful solvents in the chlorinated group, it has found a wide range of applications where superior solvency is important. Vulcan's methylene chloride is available in Technical, Aerosol, Degreasing, Special and Decaffeination grades. The Technical and Decaffeination grades meet the requirements of the American Chemical Society **Reagent Chemical Specifications**, 7th Edition, 1987, the **Food Chemicals Codex**, 3rd Edition, the **National Formulary XVI** and Military Specification MIL-D-6998D.

Physical Properties

Formula	CH_2Cl_2
Molecular Weight	84.94
Boiling Point	40.1°C; 104.2°F
Density	10.98 lbs./gal. @ 25°C
Specific Gravity @ 25/25°C	1.320
Freezing Point	-96.7°C; -142.1°F
Viscosity @ 25°C	0.430 cP
Flash Point	None
Latent Heat of Vaporization @ b.p.	78.7 cal/g; 141.7 BTU/lb
Specific Heat, liquid @ 20°C	0.276 cal/g/°C
Solubility @ 25°C	
water in solvent	0.170g/100g solvent
solvent in water	1.32g/100g water

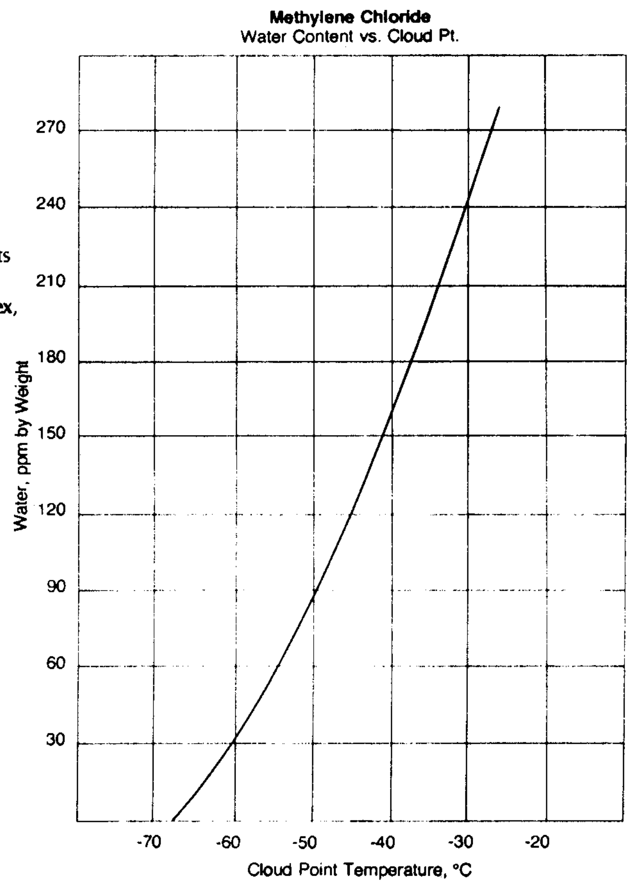


Table 3.39: Isopropyl Chloride *(7)*

$CH_3CHClCH_3$

Boiling point	35.4°C
Freezing point	-117°C
Refractive index	1.3811
Solubility in water @12.5°C	0.344
Specific gravity @20/4°C	0.8590 g/100 g
Viscosity @22.5°C	0.2962 centipoise
Weight per gallon	7.5 lb

Table 3.40: Methyl Chloride *(23)*

Monochloromethane CH_3Cl

PHYSICAL PROPERTIES

Molecular Weight	50.49
Boiling Point, 760 mm. Hg	− 23.7° C. (− 10.7° F.)
Freezing Point	− 97.6° C.
Vapor Pressure, mm., Hg. at 0° C.	1892
psia at 0° C.	36.6
Flammable limits, (percent by volume in air)	10.7-17.4
Flash Point	− 50° F calculated
Heat of Vaporization,	
cal /gm. at b.p.	102.45
Heat of Fusion, Cal./mole	1537
Heat of Combustion Kcal./mole	164.2
Specific Heat, cal./gm. ° C.	
Liquid at 20° C.	0.381
Vapor at 25° C. and 1.021 atmos.	0.199
Critical Temperature	143.1° C. (289.4° F.)
Critical Pressure, atmos.	65.9 (968.7 psia.)
Critical Density, gm./cc.	0.353
Refractive Index, liquid at − 23.7° C.	1.3712
Vapor at 25° C.	1.000703
Solubility, cc/100 cc. solvent at 20° C.	
Water	303
Benzene	4723
Carbon Tetrachloride	3756
Acetic Acid	3679
Ethyl Alcohol	3740

(continued)

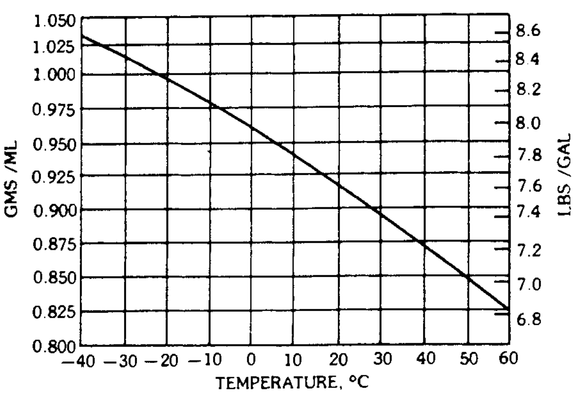
Table 3.40: (continued)

Thermodynamic Properties of Methyl Chloride (Ideal Gas State)

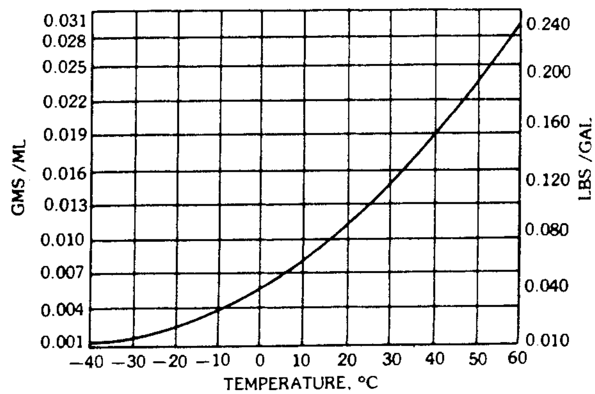
T TEMP °K	$C°_p$ HEAT CAPACITY CAL /DEG / MOLE	$H°_T - H°_{298.15}$ HEAT CONTENT CAL /MOLE	$S°_T$ ENTROPY CAL /DEG / MOLE	$\frac{F° - H°_{298.15}}{T}$ FREE ENERGY FUNCTION CAL /DEG / MOLE	FORMATION FROM ELEMENTS: HEAT $\Delta H°_f$, CAL /MOLE	FORMATION FROM ELEMENTS: FREE ENERGY $\Delta F°_f$ CAL /MOLE	$LOG_{10}K_p$
298	9.73		55.80	55.80	-20630	-14952	10.960
300	9.76	18	55.86	55.80	-20642	-14918	10.868
400	11.50	1080	58.91	56.21	-21283	-12907	7.052
500	13.28	2332	61.70	57.04	-21825	-10750	4.699
600	14.64	3707	64.19	58.02	-22313	- 8495	3.094
700	15.92	5236	66.55	59.07	-22699	- 6144	1.918
800	17.03	6885	68.75	60.15	-23012	- 3764	1.028
900	17.76	8400	70.30	60.97	-23494	- 1111	.269
1000	18.86	10480	71.75	61.27	-23444	2086	- 455
1100	19.60	12400	74.58	63.31	-23586	3551	- 705
1200	20.26	14400	76.32	64.32	-23673	6027	- 1.097
1300	20.82	16450	77.97	65.32	-23747	8493	- 1.427
1400	21.32	18560	79.52	66.27	-23789	10987	- 1.715
1500	21.75	20720	81.01	67.20	-23803	13502	- 1.967

*ACTUALLY IS 298.15° K.

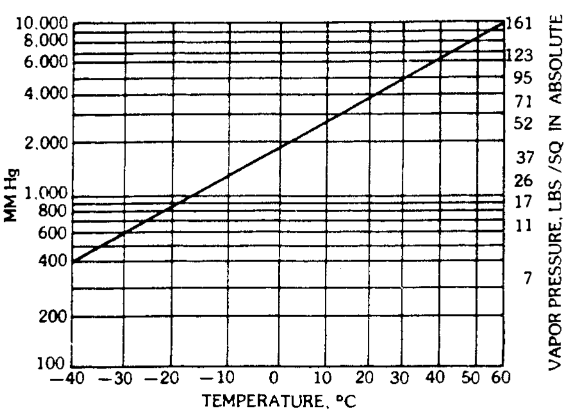
Density of Liquid Methyl Chloride



Density of Saturated Methyl Chloride Vapor

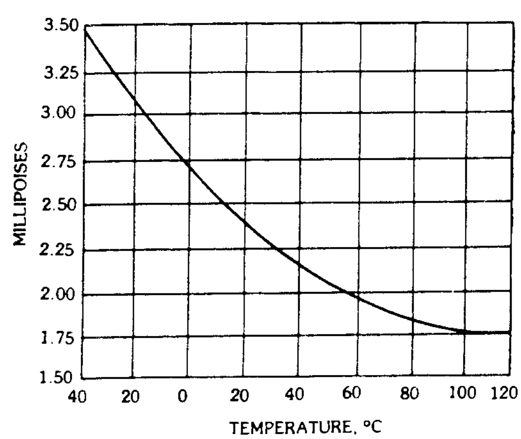


Vapor Pressure of Methyl Chloride



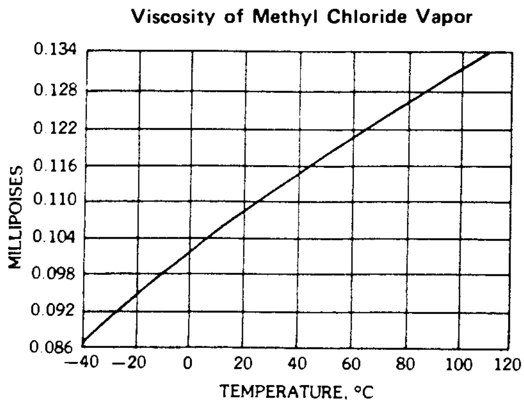
ref. D. B. Stull, Ind. Eng. Chem. *39*, 517 (April, 1947)

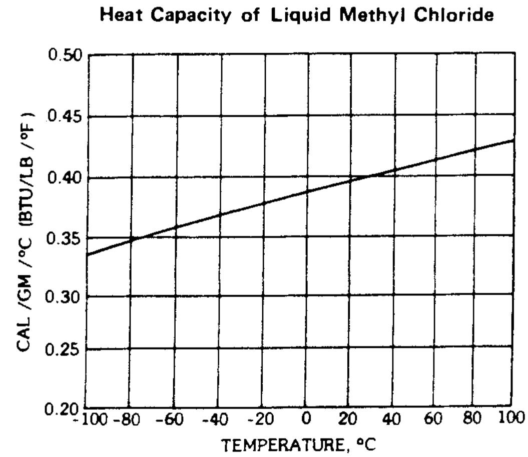
Viscosity of Liquid Methyl Chloride

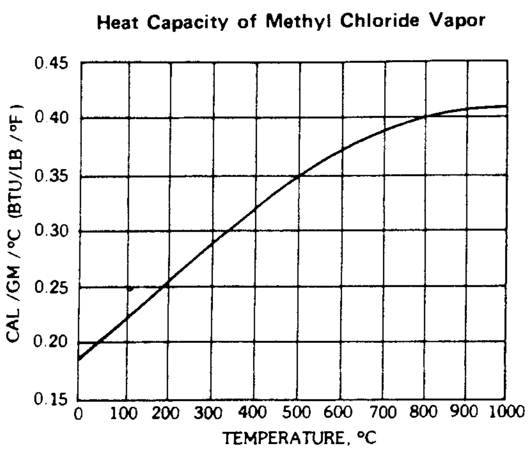


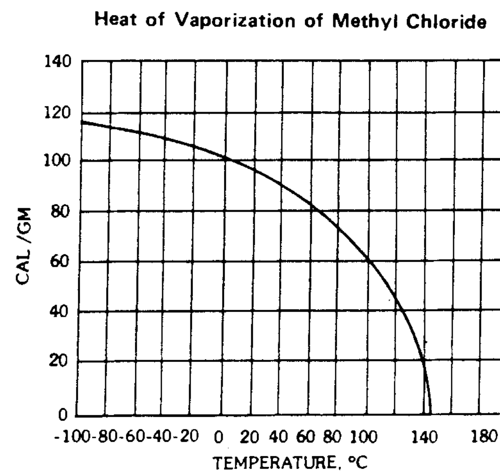
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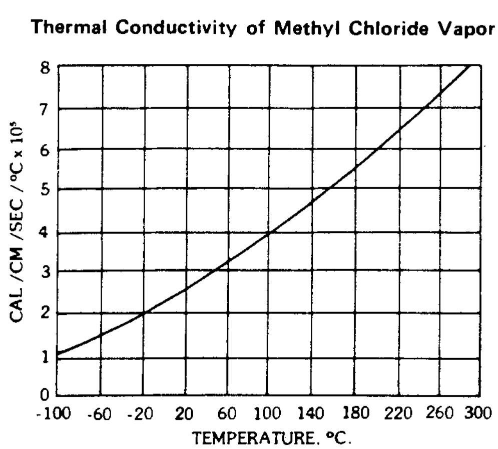
Table 3.40: (continued)











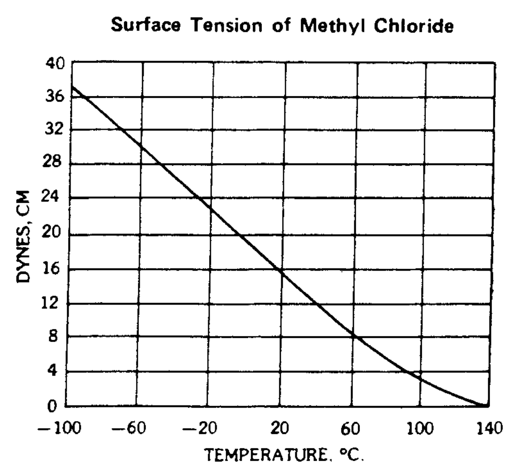


Table 3.41: Monochlorohydrin *(7)*

$ClCH_2CH(OH)CH_2OH$

PHYSICAL PROPERTIES

Boiling point	213°C
Boiling range	213-228°C (decomposes)
Specific gravity @18°C	1.326

Table 3.42: Pentachloroethane *(7)*

$CHCl_2{-}CCl_3$

PHYSICAL PROPERTIES

Acidity as HCl	0.001% by wt, max.
Boiling point @760 mm	161.9°C
Coefficient of cubical expansion Av./°C, liquid	0.0009097
Color (Saybolt)	18 max.
Explosion limits	None
Flash point	Nonflammable
Free halogen	None
Freezing point	-22.0°C
Latent heat of vaporization @B.P.	43.6 cal/g 78.4 Btu/lb
Nonvolatile matter	0.0007% by wt, max.
Refractive index	1.5035
Solubility in water @25°C	0.05 g/100 g
Solubility of water in solvent @20°C	0.24 g water/100 g
Specific gravity @20.4°C	1.678
Specific heat Liquid, 20°C	0.215 cal/g/°C
Vapor density (B.P. and 760 mm)	568 g/liter
Vapor pressure @30°C	6 mm
Viscosity liquid @20°C	2.45 centipoises
Weight per gallon @20°C	14.00 lb

PENTACHLOROETHANE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
3	Acetamide	160.5
26	Butyric acid	156.8
97	Camphene	159.3
9.9	Chloroacetic acid	158.7
36	Cyclohexanol	157.9
28	Cyclohexanone	165.4
22.5	1,3-Dichloro-2-Propanol	159.7
32	Dimethyl oxalate	157.6
65	Ethyl lactate	153.5
50	2-Furaldehyde	155.2
15	Glycol	154.5
46	Hexyl alcohol	155.8
50	Isoamyl propionate	158.7
43	Isobutyric acid	152.9
9	Isovaleric acid	160.3
56	Mesitylene	166.0
97	Methylheptenone	173.3
9.5	Phenol	160.9
89	α-Pinene	155.6

Table 3.43: Perchloroethylene *(22)*

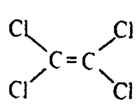
PERCHLOR

TYPICAL PROPERTIES

Perchlorethylene is a clear, water-white liquid at ordinary temperatures. It is completely miscible with most organic liquids. The stabilized product, Perchlor, can be used with any of the common construction metals.

Chemical Names: Tetrachloroethylene: perchloroethylene

Chemical Formula: CCl_2CCl_2;



Heat of Vaporization at 760 mm Hg.	cal/g	50.1
	Btu/lb	90.2
Vapor Density at 121.1°C and 760 mm Hg.	g/l	5.22
	lb/ft³	0.326
Specific Gravity of Vapor (air = 1)		5.83
Vapor Pressure at 20°C, mm Hg		14.2

Table 3.43: (continued)

TYPICAL PROPERTIES

Molecular Weight	165.85	Evaporation Rate at 77°F	
Boiling Point, °F	250.0	(25°C) (ether = 100)	9
°C	121.1	$gal/(ft^2)(day)$	0.15
Freezing Point, °F	−8.2	Flammability	Nonflammable
°C	−22.3	Viscosity at 20°C, cps	0.88
Pounds per Gallon at		Solubility at 25°C,	
68°F (20°C)	13.57	g Perchlor/100 g water	0.015
Kilograms per Liter		g water/100 g Perchlor	0.0105
at 20°C	1.63	Azeotrope with Water,	
Refractive Index, n_D^{20}	1.5053	Boiling Point, °F	189.2
Dielectric Constant at		°C	87.7
1000 cps and 25°C	2.365	Azeotropic Water Content, wt %	15.8
Specific Heat at 20°C			
cal/(g) (°C) or Btu/(lb) (°F)	0.205	Permissible Exposure Limit	
Flash Point (Tag open cup)	None	(8-hour TWA) ppm	100
Fire Point (Tag open cup)	None		

Specification and Typical Analysis, PPG Perchlor, All Grades:

	Specification	Typical Analysis
Appearance	Clear, free of suspended matter	Clear, free of suspended matter
Color, APHA	15 maximum	8
Odor	Characteristic; no residual	Characteristic; no residual
Spot Test	No spot or stain	No spot or stain
Specific Gravity, 20°C/20°C	1.623 to 1.628	1.624
Nonvolatile Residue, wt %	0.0025 maximum	0.0003
Free Chlorine	None	None
Moisture	No cloud at 0°C	No cloud at −5°C
Distillation Range (100%), °C	120.0 to 122.0	120.8 to 121.6
°F	248.0 to 251.6	249.4 to 250.9
pH	—	Drycleaning, 6.8 Degreasing, 8.4

Perchloroethylene *(53)*

Water Content vs. Cloud Pt.

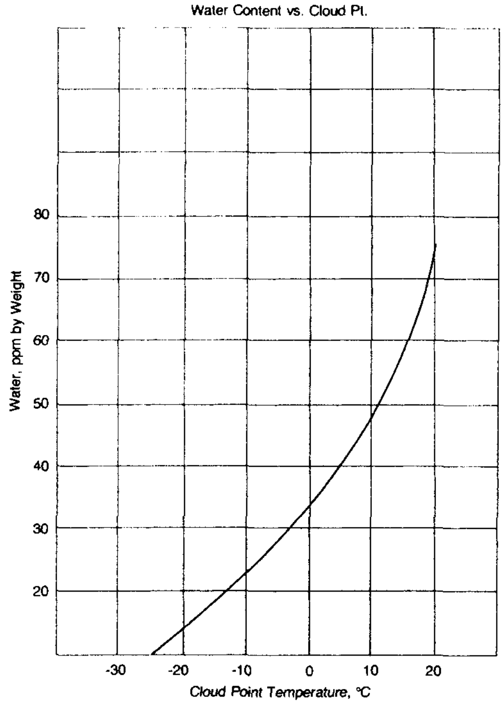


Table 3.44: Propylene Chlorohydrin *(7)*

Chloroisopropyl Alcohol $CH_3CHOHCH_2Cl$

Propylene chlorohydrin is a colorless liquid with a milk odor; it is freely soluble in water. It is largely used in organic syntheses, for the purpose of introducing the hydroxypropyl group.

PHYSICAL PROPERTIES

Acidity as HCl	0.02% by wt
Absolute viscosity @20°C	4.7 centipoises
Apparent specific gravity @20/20°C	1.1128
Boiling point @760 mm Hg @ 50 mm Hg @ 10 mm Hg	127.4°C 59°C 31°C
Coefficient of expansion @55°C	0.00097
Constant-boiling mixture @760 mm: Chlorhydrin approx. 46% Water 54%	B.P. 95.4°C
Flash point (Cleveland O.C.)	125°F
Molecular weight	94.54
Solubility in water	Miscible in all proportions
Vapor pressure @20°C	4.9 mm Hg
Weight per gallon @20°C	9.29 lb

Table 3.45: Propylene Dichloride *(7)*

1,2-Dichloropropane

Propylene Chloride

$CH_3CHClCH_2Cl$

PHYSICAL PROPERTIES

Acidity as HCl	0.005% max.
Boiling point	95.9°C
Boiling range @760 mm	93-99°C
Coefficient of expansion per °C	0.001108-20°C 0.001153-55°C
Dielectric constant, 85.8 kilocycles	8.925 recip. ohms @26°
Explosive limits in air	Lower = 3.14% by vol. @25°C Upper = 14.5% by vol. @100°C
Flash point (ASTM O.C.)	21°C
Free halogen	None
Freezing point	-70°C
Ignition temperature in air	557°C
Latent heat of vaporization @B.P.	72.2 cal/g
Nonvolatile matter	0.005 g/100 cc, max.
Refractive index	1.4418
Solubility in water @20°C	0.26% by wt
Solubility of water in solvent @20°C	0.07% by wt
Specific gravity @20/20°C	1.157-1.163
Specific heat Liquid, 20°C	0.31 cal/g/°C or Btu/lb/°F
Surface tension @25°C	31.4 dynes/cm
Vapor density (B.P., 760 mm)	3.72 g/liter
Vapor pressure @20°C	35.8 mm
Viscosity @20°C	0.00865 poise
Weight per gallon @20°C	9.65 lb

Table 3.46: 1,1,2,2-Tetrachloroethane *(7)*

Acetylene Tetrachloride
Bonoform

$CHCl_2-CHCl_2$

Acidity as HCl	0.0027% by wt, max.
Boiling point	146.5°C
Coefficient of cubical expansion Av./°C, liquid	0.000998 (15-99°C)
Fire point	Nonflammable
Flash point	Nonflammable
Free halogen	None
Freezing point	-43°C
Heat of vaporization @B.P.	55.1 cal/g
Refractive index	1.4942
Residue on evaporation	0.00062% by wt
Solubility in water @25°C	0.32% by wt
Solubility of water in solvent @20°C	0.03% by wt
Vapor pressure @30°C	9 mm
Viscosity liquid @20°C	1.7 centipoises
Water: no cloud @-10°C	0.032% by wt
Weight per gallon @25°C	13.25 lb

1,1,2,2-TETRACHLOROETHANE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
45	Butyl propionate	152.5
3.8	Butyric acid	145.7
1.8	Chloroacetic acid	146.3
55	Cyclohexanone	159.1
74	2-Ethoxyethyl acetate	158.2
27	Ethyl chloroacetate	147.5
39	Ethyl orthoformate	151.5
97	2-Furaldehyde	161.6
9	Glycol	145.1
32	Isoamyl acetate	150.1
98	Isoamyl alcohol	131.3
37	Isobutyl isobutyrate	144.9
7	Isobutyric acid	144.8
15	Mesityl oxide	147.5
52	Methyl lactate	143.3
60	Propionic acid	140.4
34	Propyl butyrate	150.2
45	Styrene	143.5

Table 3.47: Tetrachloroethylene *(27)*

Perchloroethylene

Tetrachloroethene

$CCl_2{=}CCl_2$

PHYSICAL PROPERTIES

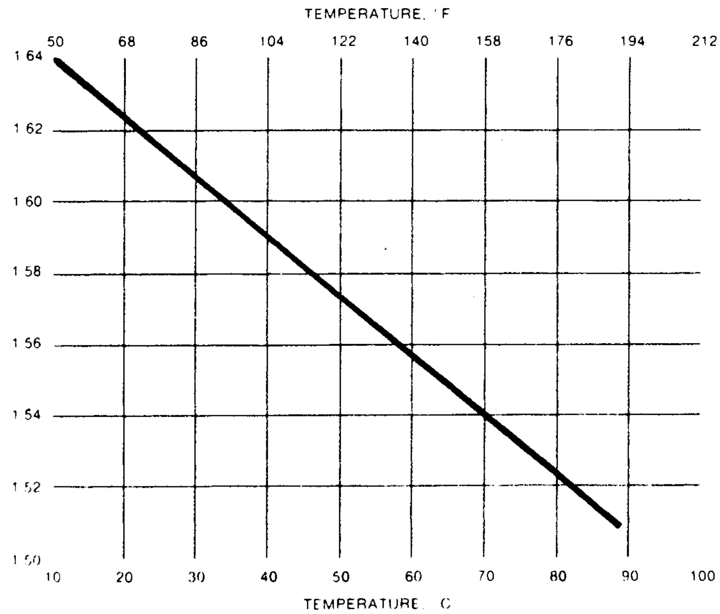
Acidity as HCl	0.001% by wt, max.
Boiling point	121.0°C
Boiling range @760 mm	120-122°C
Coefficient of cubical expansion Av./°C, liquid	0.001079 (15-90°C)
Color (Saybolt)	22
Dielectric constant, 1000 cycle	2.20
Dielectric strength, 0.1" gap	30,000 volts
Explosive limits	None
Fire point	Nonflammable
Flash point	Nonflammable
Freezing point	-22.4°C
Latent heat of vaporization @B.P.	50.1 cal/g
Nonvolatile matter	0.0007% by wt, max.
Power factor, 1000 cycle	0.02%
Refractive index	1.5055
Residue on evaporation	0.0106% by wt, max.
Solubility in water @25°C	0.04% by wt
Solubility of water in solvent @20°C	0.02% by wt
Specific gravity @25/25°C	1.618
Specific heat	0.21 cal/g/°C
Specific resistivity	1.8×10^{13} ohms/cm
Vapor pressure @30°C	28 mm
Viscosity @20°C	0.90 centipoise
Water content	0.008% by wt
Weight per gallon @25°C	13.46 lb

TETRACHLOROETHYLENE FORMS AZEOTROPES WITH:

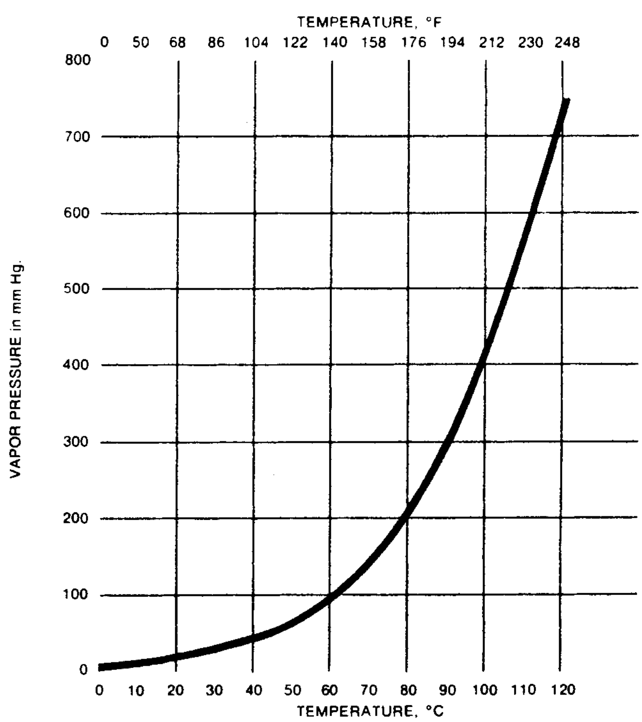
%		B.P. °C of Azeotrope
2.6	Acetamide	120.5
38.5	Acetic acid	107.4
46	Allyl alcohol	93.4
52	1-Bromo-3-Methylbutane	119.3
29	Butanol	109.0
24.3	2-Chloroethanol	110.0
26	Diethyl carbonate	118.6
51.5	Epichlorohydrin	110.1
63	Ethanol	76.8
43	Ethyl butyrate	119.5
6	Glycol	119.1
20	Isoamyl alcohol	116.1
35	Isoamyl formate	117.9
40	Isobutanol	103.1
70	Isopropanol	81.7
3	Isobutyric acid	120.5
53	Isobutyl acetate	115.5
35	Isobutyl ether	119.5
55	Isopropyl isobutyrate	119.0
24.5	2-Methoxyethanol	109.7
42	Isobutyl nitrate	117.0
52	4-Methyl-2-Pentanone	113.9
32	Paraldehyde	118.8
48	Propanol	94.1
8.5	Propionic acid	119.2
19.5	Pyrrol	113.4
43	1,1,2-Trichloroethane	112.0
52	Triethyl borate	117.5

(continued)

Table 3.47: (continued)



Specific Gravity vs Temperature of Hooker Perchlorethylene



Vapor Pressure vs Temperature of Hooker Perchlorethylene

Table 3.48: Trichlorobenzenes *(7)*

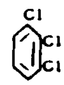
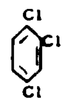
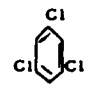
	1,2,3-TRICHLOROBENZENE	1,2,4-TRICHLOROBENZENE	1,3,5-TRICHLOROBENZENE
			
Synonym:	vic-Trichlorobenzene	uns-Trichlorobenzene	sym-Trichlorobenzene
Physical state	White crystals	Colorless liquid	White crystals
Boiling point: @760 mm	221°C (429.8°F)	213°C (415.4°F)	208.5°C (407.3°F)
Density: 25/25°C	1.69 (solid)	1.451 (liquid)	
Flash point: (Tag C.C.)	113°C (235.4°F)	110°C (230.0°F)	107°C (224.6°F)
Index ($^{19}_{D}$) of Refraction:	1.5776	1.5732	1.5662

Table 3.49: 1,1,1-Trichloroethane *(53)*

TLV-TWA Values

SOLVENT	TLV-TWA* (ppm in air)
Solvent 111® (1,1,1-trichloroethane)	350
Trichloroethylene	50
Perchloroethylene	50
Methylene Chloride	100
Chloroform	10
1,1,2-trichloroethane	10
Stoddard Solvent	100
Toluene	100
Xylene	100
Turpentine	100
Methyl Alcohol (Methanol)	200
Benzene	10

*1985-86 values

(continued)

Table 3.49: (continued)

Specifications for SOLVENT 111

General Purpose Grade

COMPONENT	SPECIFICATIONS
Appearance	Clear, free from suspended matter
Color, APHA	15 max.
Specific Gravity @ 25/25°C.	1.318 - 1.324
Distillation Range, °C.	
760 mm. IBP to DP	72 - 88
Free Halogens	None
Acidity, as HCl	0.001% by wt. max.
Nonvolatile Matter	0.001% by wt. max.
Water	0.0100% by wt. max.
Purity:	
1,1,1-trichloroethane content	96.0% by wt. min.
1,1,1-trichlorethane content	95.0% by vol. min.
Individual halogenated impurities	0.5% by wt. max.
Total halogenated impurities	1.0% by wt. max.
Acid Acceptance, as NaOH (ASTM D-2942)	0.20% by wt. min.
Aluminum Corrosion Test	Passes O-T-620c
Metals Corrosion Test	Passes MIL-T-81533A
Stability (accelerated oxidation test)	Passes MIL-T-81533A

Solvent 111®, General Purpose Grade meets requirements of Federal Specification O-T-620c (1,1,1-trichloroethane, technical) and Military Specification MIL-T-81533A (1,1,1-trichloroethane, vapor degreasing.)

Aerosol Grade

COMPONENT	SPECIFICATIONS
Appearance	Clear, free from suspended matter
Color, APHA	15 max.
Specific Gravity @ 25/25°C.	1.295 - 1.303
Distillation Range, °C.	
760 mm. IBP to DP	68 - 78
Free Halogens	None
Acidity, HCl	0.001% by wt. max.
Nonvolatile Matter	0.001% by wt. max.
Water	0.0100% by wt. max.
Purity:	
1,1,1-trichloroethane content	95.0% by wt. min.
1,1,1-trichloroethane content	95.0% by vol. min.
Individual halogenated impurities	0.5% by wt. max.
Total halogenated impurities	1.0% by wt. max.
Acid Acceptance as NaOH	0.20% by wt. min.

(continued)

Table 3.49: (continued)

Physical Properties of SOLVENT 111

Chemical Formula	CCl_3CH_3
Molecular Weight	133.4
Freezing Point, °C	-37.9
Boiling Point at 1 atm, °C	74.1
Heat of Vaporization at Boiling Point, cal/g	54.4*
Btu/lb	98*
Specific Heat, Liquid at 20°C, cal/g/°C (Btu/lb/°F)	0.25*
Critical Temperature, °C	272.5*
Critical Pressure, atm	39.8*
Thermal conductivity, Liquid at 20°C, Btu/hr/ft²/°F/ft	0.080
Specific Gravity of Liquid, 25/25°C	1.319
Liquid Density, pounds per gallon at 25°C	10.97
Average Coefficient of Cubical Expansion, Liquid, per °C, (0 to 40°C)	0.00116
Specific Gravity of Vapor at 1 atm at bp (air=1)	4.6
Viscosity, Liquid at 20°C, cP	0.86
Surface Tension at 25°C, Dynes/cm	25.5
Solubility at 25°C,	
g Solvent 111® in 100 g water	0.07
g Water in 100 g Solvent 111®	0.04
Refractive Index nD, Liquid at 20°C	1.4374*
Liquid at 25°C	1.435
Dielectric Strength, Liquid at 25°C, kV, (ASTM D 877)	25
Dielectric Constant, Liquid, 100 kHz, at 25°C (ASTM D 924)	7.0
Vapor Pressure	5
Density of Liquid	6
Flash Point (ASTM D 1310)	None
Explosion Point (ASTM D 1310)	None
Autoignition Temperature, °C	458
Flammable Range, % v in Air at 25°C	7.5 - 15.0
Evaporation Rate (Ether=100)	35

Binary Azeotropes:

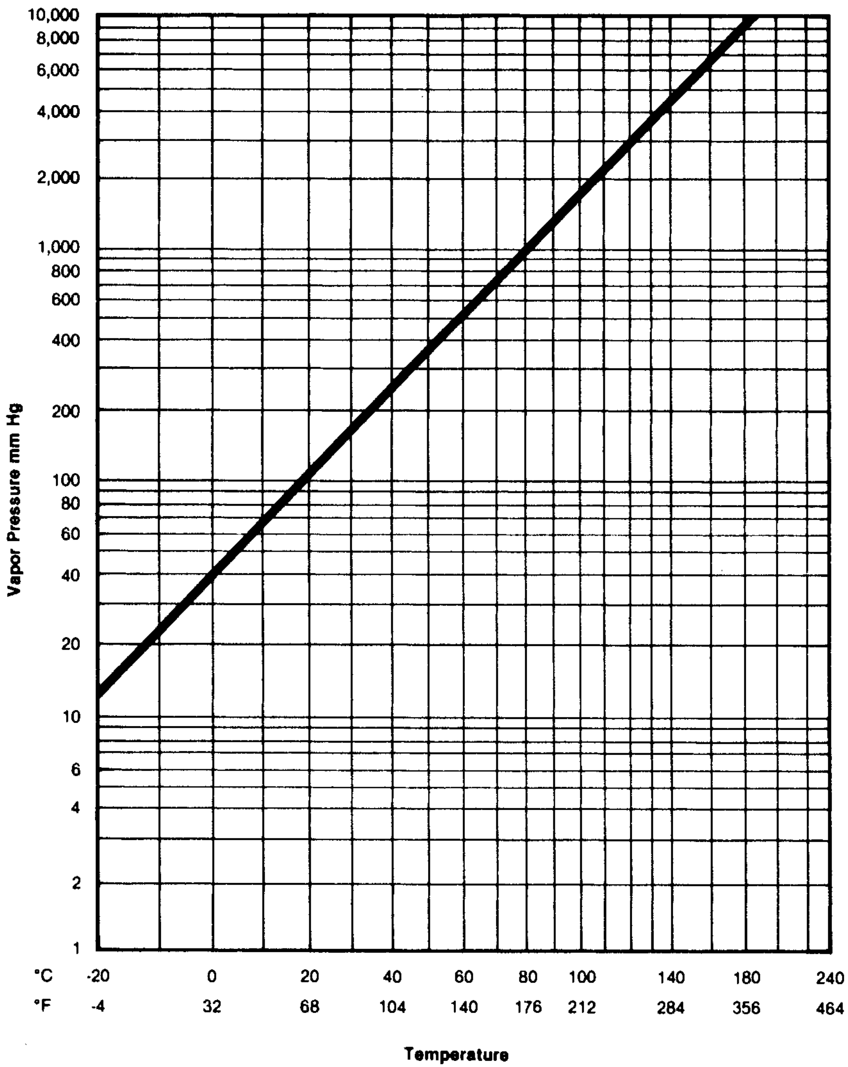
Component	% by wt	Boiling Point
Water	4.3	65.0°C (149°F)
Methanol	23.0	55.5°C (132°F)
Ethanol	17.4	64.4°C (148°F)
Isopropanol	18.2	68.7°C (155.6°F)
n-Propanol	7.1	72.3°C (162°F)
Hexane	28.9	60.0°C (140°F)

*Values for unstabilized 1,1,1-trichloroethane

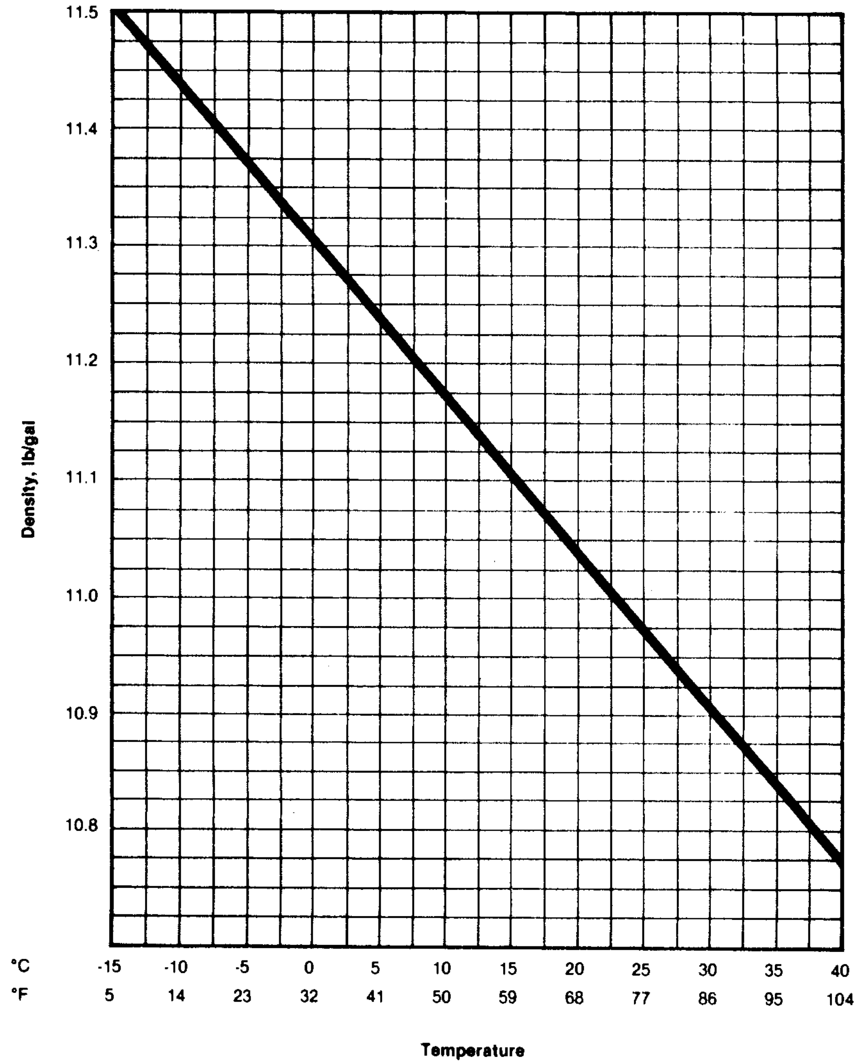
(continued)

Table 3.49: (continued)

Vapor Pressure of SOLVENT 111



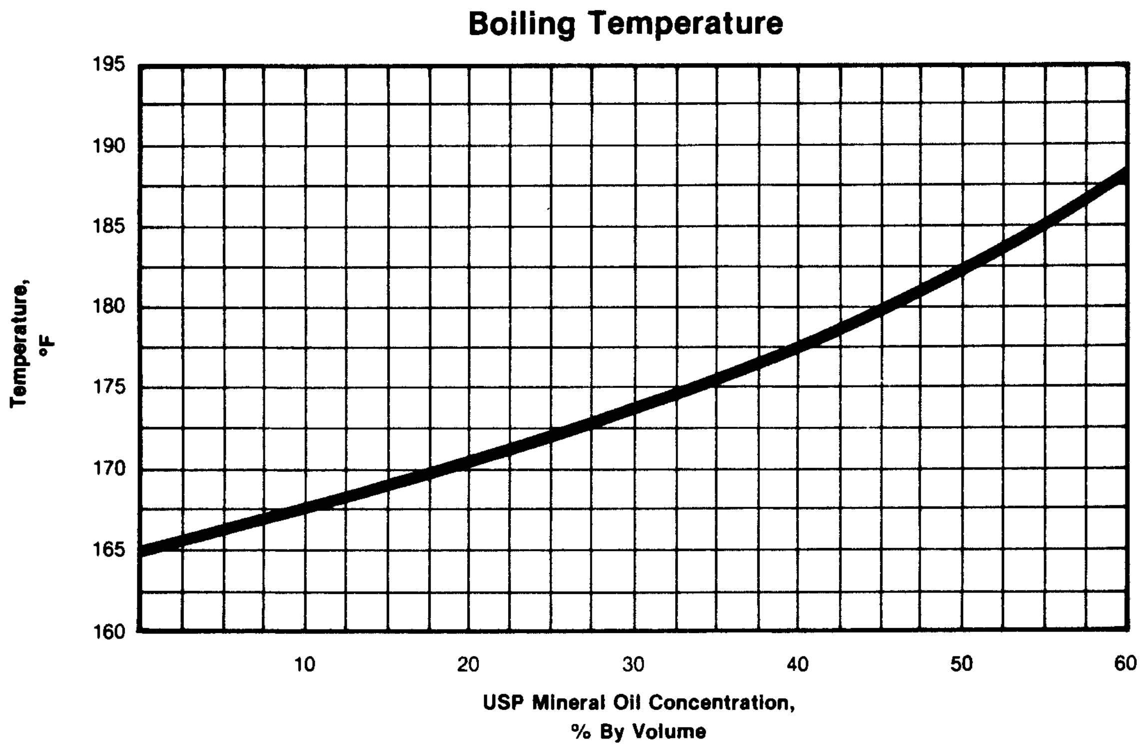
Density of SOLVENT 111

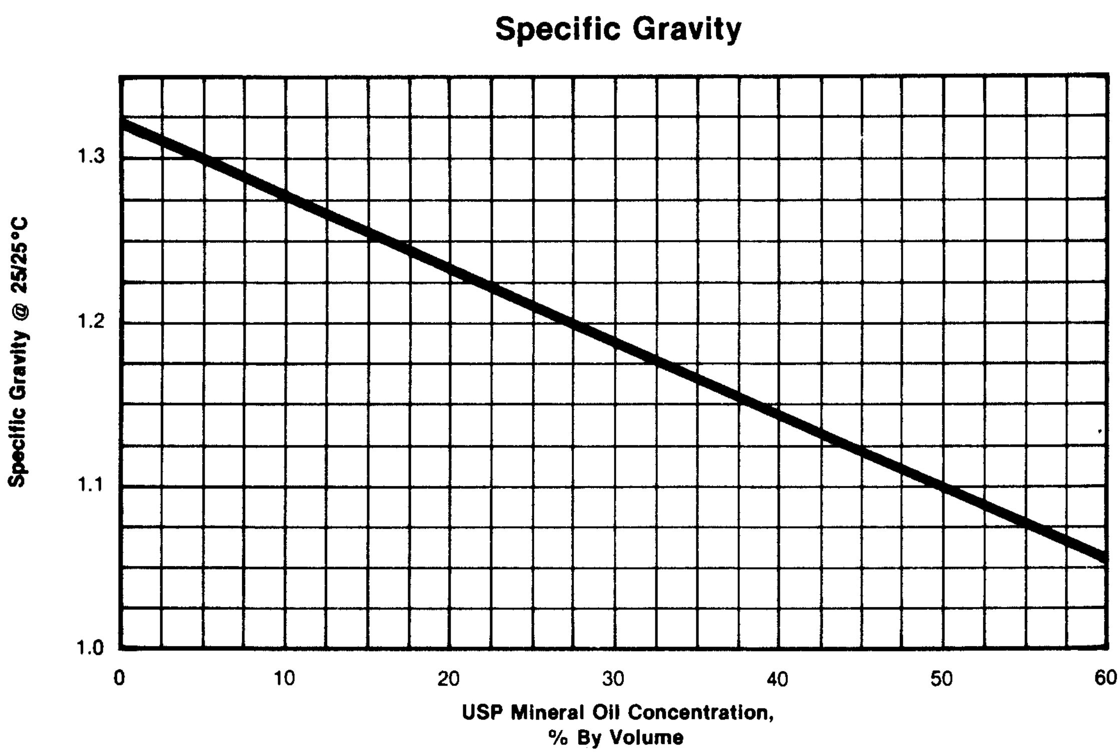


(continued)

Table 3.49: (continued)

Properties of Mixtures of SOLVENT 111 and Oil





(continued)

Table 3.49: (continued)

Comparative Physical Properties—Chlorinated Solvents

Properties	Solvent 111®	Trichloro-ethylene	Perchloro-ethylene	Methylene Chloride
Boiling Point (760mm Hg), °F (°C)	165 (74)	188 (86.7)	250 (121)	104 (39.8)
Freezing Point, °F (°C)	-36(-38)	-122(-85.5)	-9(-22)	-142(-97)
Liquid Specific Gravity, 25/25°C	1.319	1.456	1.620	1.320
Specific Heat of Liquid at 20°C, (cal/g/°C) or (Btu/lb/°F)	0.25	0.23	0.21	0.28
Heat of Vaporization,				
cal/g	54.4	57.2	50.8	78.7
Btu/lb	98.0	103	91.4	141.7
Refractive Index at 25°C	1.435	1.473	1.503	1.424
Viscosity at 20°C, cP	0.86	0.58	0.88	0.42
Density at 25°C, (lbs./gal)	10.97	12.10	13.47	10.98
Flash Point	None	None	None	None
Fire Point	None	None	None	None
Vapor Density at bp, lb/ft'	0.279	0.278	0.326	0.206
Vapor Specific Gravity (air=1.0)	4.55	4.54	5.73	2.93
Kauri-butanol value (ASTM D 1133)	124	129	90	135
Evaporation Rate,				
Ether=100	35	28	9	71
Carbon Tetra-chloride=100	100	84	39	147
Energy required to convert 1 lb. liquid at 70°F to vapor at bp and 1 atm, (Btu)	127	124	125	151
Energy required to convert 1 gal. liquid at 70°F to vapor at bp and 1 atm, (Btu)	1410	1500	1690	1660

Table 3.50: 1,1,2-Trichloroethane *(7)*

beta-Trichloroethane

Vinyl Trichloride

Ethylene Trichloride

$Cl—CH_2CH—Cl_2$

PHYSICAL PROPERTIES

Acidity as HCl	0.0001% by wt. max.
Boiling point @760 mm	113.5°C
Boiling range @760 mm	111.8-113.3°C (5-95%)
Fire point	Nonflammable
Flash point	Nonflammable
Free halogen	None
Freezing point	-36.7°C
Latent heat of evaporation @B.P.	68.7 cal/g
Nonvolatile matter	None
Refractive index	1.4711
Solubility in water @25°C	0.48 g/100 g
Solubility of water in solvent @20°C	0.03 g water/100 g
Specific gravity @20/4°C	1.441
Specific heat Liquid, 20°C	0.266 cal/g/°C
Specific resistivity	5.2×10^8 ohms/cm
Vapor density (B.P., 760 mm)	4.21 g/liter
Vapor pressure @30°C	36 mm
@90°C (194°F)	369 mm
@100°C (212°F)	505 mm
@110°C (230°F)	680 mm
@114°C (237°F)	764 mm
Water	0.007% by wt. max.
Weight per gallon @20°C	12.04 lb

Table 3.51: Trichloroethylene *(7)(27)*

1,2,2-Trichloroethylene

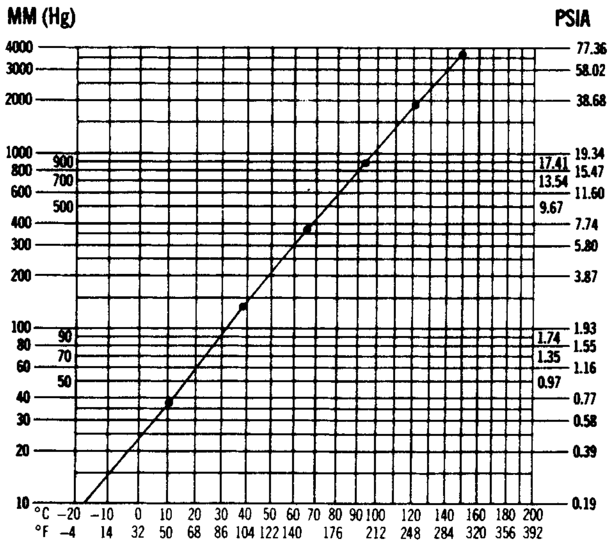
PHYSICAL PROPERTIES

Acidity as HCl	Not more than 0.001%
Boiling point	86.7°C
Boiling range @760 mm	95% or better distills from 86.0-87.5°C
Coefficient of expansion per °C	0.00115-20°C
Color (Saybolt)	24 max.
Dielectric constant, 1000 cycle	3.27
Fire point	Nonflammable
Flash point (ASTM O.C.)	None @B.P.
Free chlorine	None
Freezing point	-86.4°C
Latent heat of vaporization @B.P.	57.3 cal/g
Nonvolatile matter	0.00067% by wt. max.
Power factor, 1000 cycle	2.2%
Refractive index @27°C	1.4735
Solubility in water @25°C	0.10% by wt
Solubility of water in solvent @25°C	0.02% by wt
Specific gravity @20/20°C	1.4655
Surface tension @25°C	32.0 dynes/cm
Vapor pressure @-20°C	4.5 mm
@- 9°C	9.0 mm
@ 0°C	17.4 mm
@ 20°C	56.0 mm
@ 40°C	145 mm
@ 50°C	230 mm
@ 65°C	385 mm
@ 77°C	562 mm
Viscosity @25°C	0.00550 poise
Water content	0.002% by wt
Weight per gallon @20°C	12.20 lb

(continued)

Table 3.51: (continued)

Trichlorethylene—Vapor Pressure/Temperature Variation



Typical Boiling Point Curve of Trichloroethylene–Mineral Oil Mixture

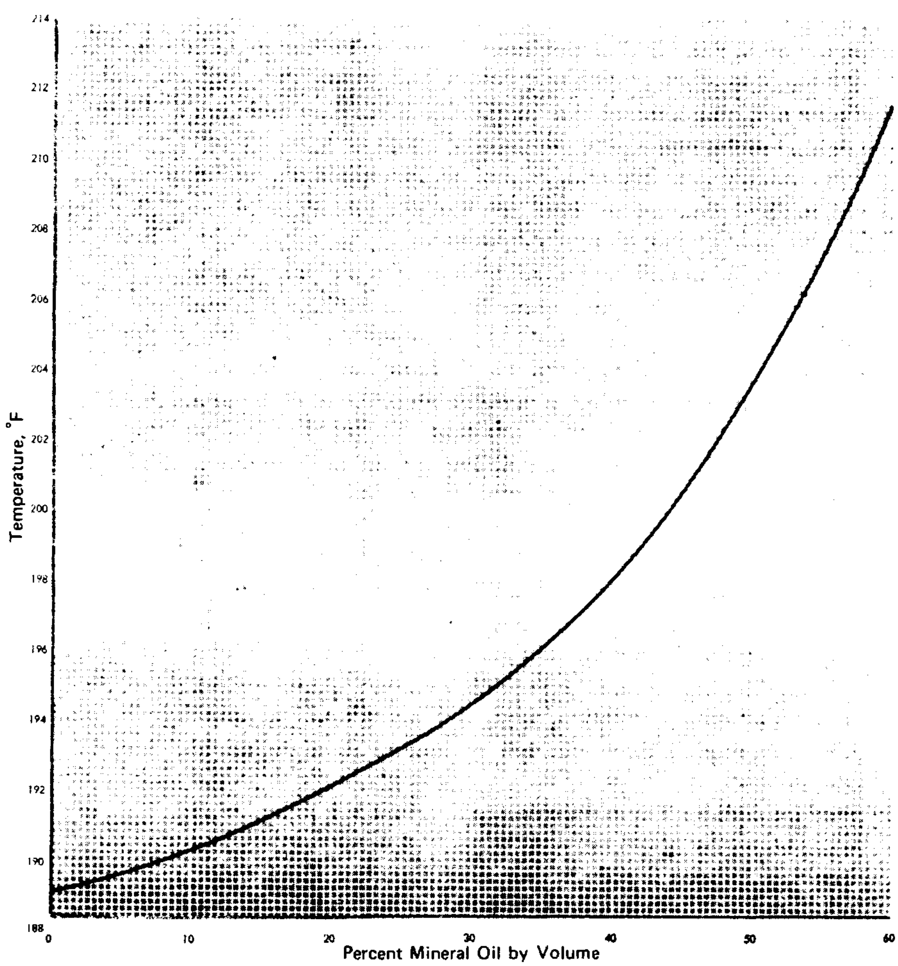


Table 3.51: (continued)

$CHCl{=}CCl_2$

TRICHLOROETHYLENE FORMS AZEOTROPES WITH:

%		B.P. °C of Azeotrope
3.8	Acetic acid	87.0
16	Allyl alcohol	81.0
7.5	tert-Amyl alcohol	86.7
2.5	Butanol	86.9
33	tert-Butanol	75.8
12	1,2-Dichloroethane	82.9
46.	Diethoxymethane	89.29
8	Isobutanol	85.4
30	Isopropanol	75.5
17	Propanol	81.8
80	Propyl formate	79.5
27	Ethanol	70.9

Trichloroethylene *(53)*

Water Content vs. Cloud Pt.

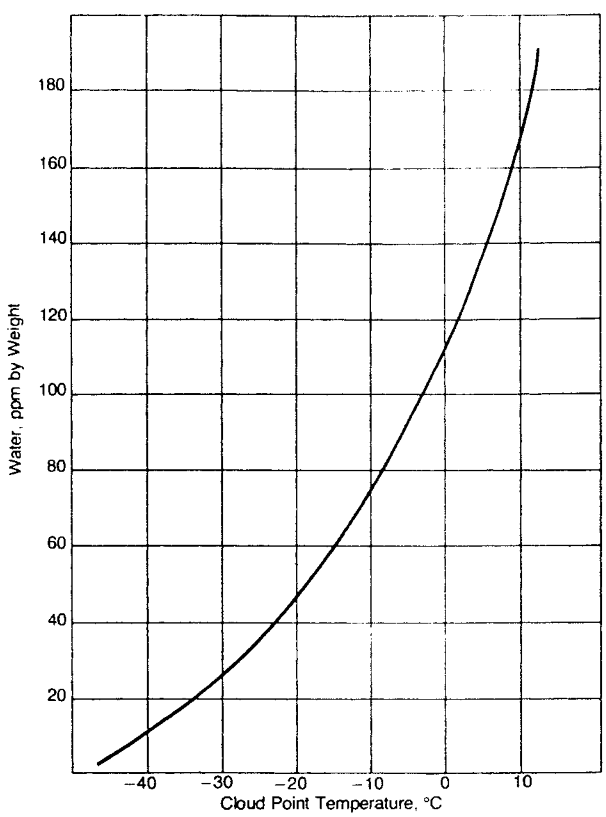


Table 3.52: Density of Chlorinated Solvents *(53)*

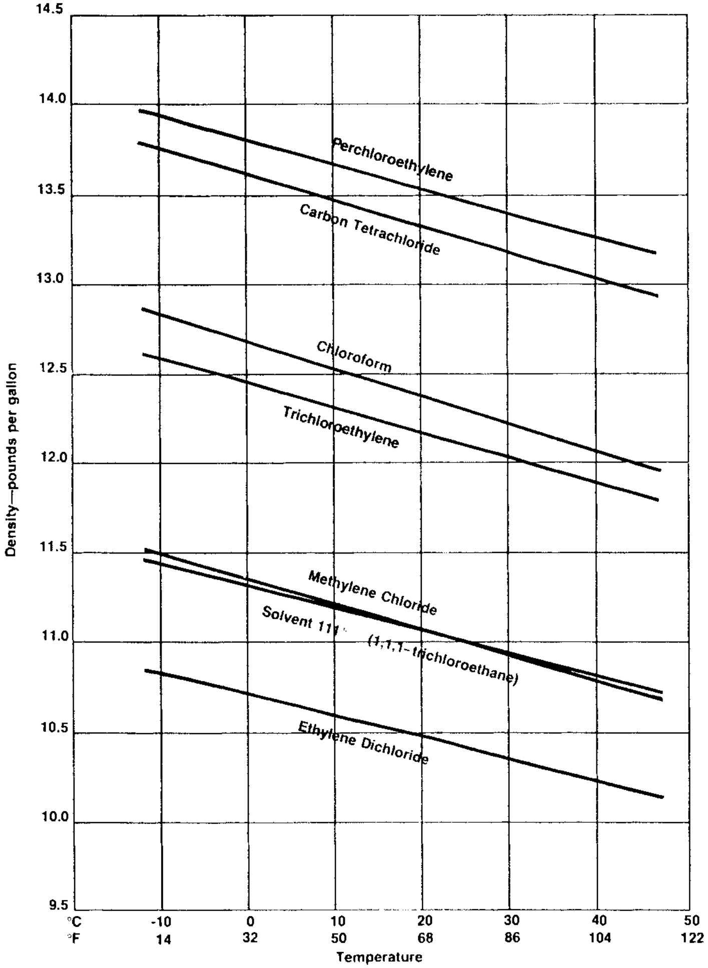


Table 3.53: Vapor Pressure of Chlorinated Solvents *(53)*

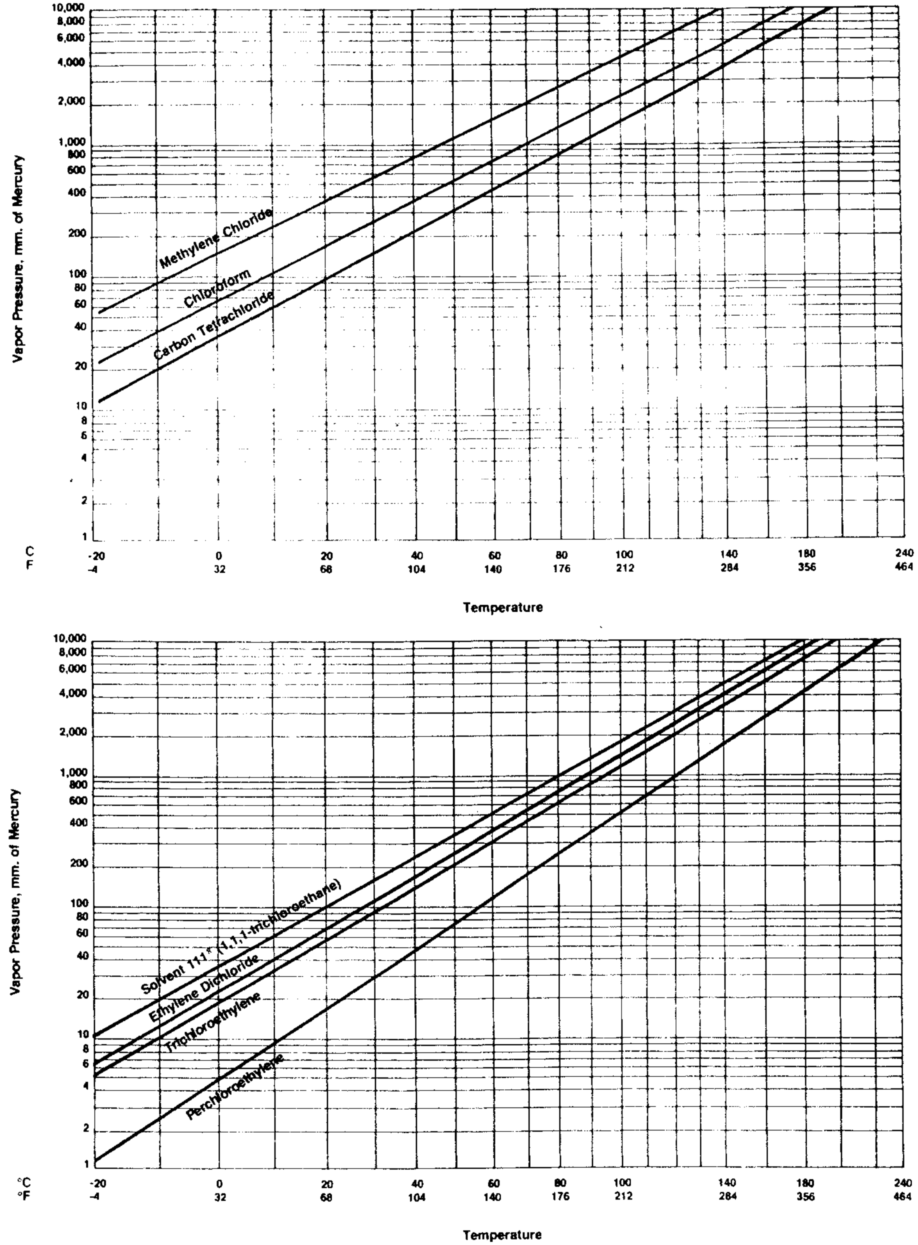


Table 3.54: Trichloropropane (7)

$CH_2ClCHClCH_2Cl$

PHYSICAL PROPERTIES

Analysis, % W	
Trichloropropane	97.0
Epichlorohydrin	1.5
Glycerol dichlorohydrin	1.5
Color, Pt-Co	15
Distillation range, IBP	150°C
90%	156.1°C
95%	156.1°C
DP	156.6°C
Flash point	165°F
Molecular weight	147.44
Refractive index	1.4832
Specific gravity @20/20°C	1.385

1,2,3-TRICHLOROPROPANE FORMS AZEOTROPES WITH

%		B.P. °C of Azeotrope
35	Camphene	152.9
30	2,7-Dimethyloctane	155.5
15	α-Pinene	150.0

Table 3.55: Triglycol Dichloride (7)

$Cl(CH_2CH_2O)_2CH_2CH_2Cl$

PHYSICAL PROPERTIES

Acidity as HCl	0.01% by wt, max.
Boiling point @760 mm	241.3°C
Boiling range @760 mm	Not more than 5% distills below 235°C Not less than 95% distills below 242°C
Color (Pt-Co scale)	25 max.
Dryness @20°C	Miscible with 19 vol. 60°Bé gasoline
Flash point (O.C.)	250°F
Solubility in water @20°C	1.89% by wt
Solubility of water in solvent @20°C	0.83% by wt
Specific gravity @20/20°C	1.1950-1.2000
Vapor pressure @20°C	0.06 mm
Weight per gallon @20°C	9.97 lb

Table 3.56: Vinyl Chloride *(7)*

Monochloroethylene $CH_2{=}CHCl$

PHYSICAL PROPERTIES

Acetaldehyde	Not more than 0.5% by wt
Boiling point @760 mm	-13.9°C
Boiling range @760 mm	Not less than 95% distills over before the temperature of the liquid reaches 10°C
Color	Water-white
Freezing point	-159.7°C
Heat of evaporization	81.6 cal/g
Residue	Not more than 0.5% by vol.
Specific gravity @B.P.	0.97
Specific heat	0.27 cal/g/°C
Solubility in water @25°C	Slightly soluble
Weight per gallon @20°C	7.59 lb

Table 3.57: Vinylidene Chloride *(23)*

Molecular Weight (theoretical)	96.95
Odor	Pleasant, Sweet
Appearance	Clear liquid
Color	10-15 APHA
Solubility of monomer in H_2O at 25°C, weight %	0.021
Solubility of H_2O in monomer at 25°C, weight %	0.035
Boiling Point (760 mm Hg), °C	+ 31.56
Freezing Point, °C	−122.5

Vapor Pressure

$\log P_{mm} = 6.98200 - 1104.29/(t + 237.697)$

Temperatures calculated at selected pressure

Pressure (mm Hg)
760
400
200
100
60
40
20
10
5
1

(continued)

Table 3.57: (continued)

Liquid density

Temperature (°C)
−20
0
+20

Pounds/gallon

Temperature (°C)
−20
0
20

Index of Refraction

Temperature (°C)	
10	1.43062
15	1.42777
20	1.42468

Absolute Viscosity

Temperature (°C)	Viscosity (cps)
−20	0.4478
0	0.3939
+20	0.3302

Flash Point (Tag closed cup), °F	0
Explosive limits in air (28°C), %	7.3 - 16.0
Auto-ignition temperature, °F	1058
Q Value	= 0.22
e Value	= 0.36
Latent Heat of Vaporization, ▲Hv cal/mole at 25°C	= 6,328 ± 0.3%
at Boiling Point	= 6,257 ± 0.3%
Latent Heat of Fusion, ▲Hm cal/mole	= 1,557
Heat of Polymerization, ▲Hp k cal/mole at 25°C	= −18.0 ± 0.9
▲Hp BTU/lb at 77°F	= 334 (exothermic)
Heat of Combustion, Liquid Monomer ▲Hc k cal/mole	= 261.93 ± 0.3
Heat of Formation, Liquid Monomer, ▲H_f k cal/mole	= −6.0 ± 0.3
Gaseous Monomer, ▲H_f k cal/mole	= +0.3 ± 0.3
Heat Capacity, Liquid Monomer, C_p cal/mole deg at 25.15°C	= 26.745
Heat Capacity, Ideal Gas State C_p cal/mole deg at 25.15°C	= 16.04
Critical Temperature, T_c °C	= 222
Critical Pressure, P_c Atmospheres	= 51.3
Critical Volume, V_c cm^3/mole	= 219

COMPARATIVE DATA

Table 3.58: Alpha Cleaning Solvents *(62)*

Alpha 564M and 565

Alpha 564M and 565 are functionally azeotropic blends of a chlorinated solvent and a polar component, designed for effective cleaning of post-soldering flux residues from pcb's and other electronic assemblies. Both formulations have no flash points. Compared to the fluorocarbons, they are more aggressive, more effective cleaners, yet lower in cost.

564M

Perchlorethylene and propylene glycol monomethyl ether.

565*

1,1,1,-Trichloroethane and n-propyl alcohol.

PHYSICAL PROPERTIES[1]

Property	564M	565
Specific Gravity	1.540 ± 0.010	1.285 ± 0.005
Lb./Gal.	12.81	10.69
Residue on Evaporation (ppm max.)	25	10
Alkalinity (calc. as ppm NaOH)	50 (max.)	—
Acidity (calc. as ppm HCl)	—	10 (max.)
Acid Acceptance (calc. as Wt. % NaOH)	0.07, Min.	0.15, Min.
Appearance clarity	Clear	
color (Max. A.P.H.A.)	40	15
Boiling Point	118°C (244°F)	74°C (165°F)
Freezing Point	<0°C (<32°F)	−34 C (−30°F)
Vapor Density at Boiling Point (lb./cu. ft)[2]	0.307	0.272
Latent Heat of Vaporization at Boiling Point (Btu/lb.)[2]	100	133
Specific Heat (Btu/lb./°F)[2]	0.244	0.268
Vapor Pressure (mm Hg)[2] @ 20°C	14.0	92.8
Surface Tension (dyne/cm.) @ 20°C[2]	31.9	25.0
Kauri-Butanol Value	182	206
Evaporating Rate (relative)[3]	0.21	0.55
Solubility of Water in Solvent (grams/100cc)	<0.1	0.2
Toxicity (TLV)[2]	100	345
Flash Point[4]		
Tag Open Cup	NONE	
Tag Closed Cup	NONE	
Fire Point	NONE	

NOTES:

1. Unless specified, properties are at room temperature (25°C; 77°F) and 1 atmosphere (760 mm Hg).
2. Calculated values.
3. Relative evaporation rate calculated with a value of 1.00 assigned to FC113.
4. As per OSHA recommendations.

Alpha 1001 and 1003

Alpha 1001 and 1003 are azeotropes of Fluorocarbon 112 (tetrachlorodifluoroethane) and polar alcohols formulated for effective cleaning of post-soldering flux residues from pcb's and other electronic assemblies. Compared to chlorinated solvents, they are less aggressive and can be used on normally solvent-sensitive plastic materials. They are more effective solvents than Fluorocarbon 113 (trichlorotrifluoroethane)-based products, because of the extra chlorine atom.

1001

Contains 28% isopropyl alcohol and has a Tag Open Cup Flash Point of 85°F.

1003

Contains 15% n-propyl alcohol and has no TOC Flash Point below its boiling point of 180°F.

SPECIFICATIONS[1]

Property	1001	1003
Specific Gravity	1.254 ±0.020	1.423 ±0.020
Lb./Gal.	10.42	11.83
Residue on Evaporation (ppm max.)	5	
pH of Water Extract	Neutral	
Min. Acid Acceptance (cal. as Wt. % NaOH)	0.50	0.22
Appearance clarity	Clear	
color (Max. A.P.H.A.)	15	
Boiling Point	76°C (168°F)	82°C (180°F)
Freezing Point	−14°C (6°F)	6°C (43°F)
Vapor Density at Boiling Point (lb./cu. ft.)[2]	0.268	0.323
Latent Heat of Vaporization at Boiling Point (Btu/lb.)[2]	128	100
Specific Heat (Btu/lb./°F)[2]	0.323	0.271
Vapor Pressure (mm Hg)[2]	42.0	39.7
Kauri-Butanol Value[3]	71	
Evaporation Rate (relative)[4]	0.53	
Solubility of Water in Solvent (grams/100 cc)	5.6	1.8
Toxicity (TLV)[2]	470	455
Flash Points[5]		
Tag Open Cup	29°C (85°F)	None to Boiling
Tag Closed Cup	None	None
Fire Point	29°C (85°F)	None

Notes:
[1]Unless specified, properties are room temperature (25°C; 77°F) and 1 atmosphere (760 mm Hg).
[2]Calculated values.
[3]Major constituent only.
[4]Relative evaporation rate calculated with a value of 1.00 assigned to F113.
[5]As per OSHA recommendations. Use of Cleveland Open Cup Test yields values significantly higher.

Table 3.59: Ashland Chlorinated Solvents *(69)*

PRODUCT	LB./GAL. 25°/25°C	SP. GR. 25°/25° C	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F TCC	EVAP. RATE[1]
Methylene Chloride	11.0	1.321	39.4-40.4	103-105	None	14.5
Chloroform	12.3	1.481	60-62	140-143	None	—
1, 1, 1-Trichlorethane	10.9	1.312	72-88	162-190	None	4.6
Carbon Tetrachloride	13.2	1.582	76-77	169-171	None	6.0
Ethylene Dichloride	10.5	1.260	83-85	180-184	70	4.5
Trichlorethylene	12.1	1.456	86-88	187-190	None	2.6
Propylene Dichloride	9.6	1.157	92-99	198-210	64	3.2
Perchlorethylene	13.5	1.619	120-122	248-252	None	2.1
Monochlorobenzene	9.2	1.101	131-133	268-271	82	1.07
Orthodichlorobenzene	10.9	1.308	180-183	356-361	155	0.15

[1] n-Butyl Acetate = 1

Table 3.60: Chemcentral Chlorinated Solvents *(67)*

CHLORINATED SOLVENTS	CAS	Mole Weight	Specific Gravity @ 25/25°C	Pounds Per Gallon @ 25°C	Coeff. of Expan. Per °C	△Spec. Gravity Per °C	Refrac-tive Index @ 25°C	Distillation Range @ 760 mm Hg °C	Distillation Range @ 760 mm Hg °F
1.1.1. TRICHLOROETHANE	71 55-6	133 4	1.320	10 97	0.00125	0014	1.434	74-90	165-194
ETHYLENE DICHLORIDE	107-06-2	99 0	1 252	10.42	0.00117	0012	1.4427	81.5-85.5	179-186
METHYLENE CHLORIDE TECH.	75-09-2	84 9	1.320	10 98	0.0014	0016	1 421	40.0-40.8	104-105.5
MONOCHLOROBENZENE	108-90-7	112 6	1.105	9.19			1.5215	131.7-132	269-270
ORTHODICHLOROBENZENE	**95-50-1**	**147.0**	**1.303**	**10.84**	**0.00083**	**.0006**	**1.5482**[a]	**180-183**	**356-362**
PERCHLORETHYLENE	127-18-4	165.8	1.619	13.47	0.00102	0012	1.5029	121-123	250-254
TRICHLORETHYLENE—Extract'n	79-01-6	131 4	1.459	12.14	0.00117	00006	1.478[b]	87-88	188-190
TRICHLORETHYLENE—Degr'g	79-01-6	131 4	1 456	12.11	0.00117	00006	1.478[b]	87-88	188-190
CC #49			1 370	11.41	0.0013	0015	1.44	39-123	103-254
SC #49 COLD DEGREASER			**0.939**	**7.82**				**42-201**	**108-386**
SC #149 COLD DEGREASER			0.947	7.89				42-160	108-320

CHLORINATED SOLVENTS	Vapor Press. @ 20°C mm Hg	Evaporation Rate Minutes	Evaporation Rate Carbon Tet = 1	Evaporation Rate n-Butyl Ace. = 1	Kauri Butanol Value cc.	Freeze Point °C	Flash Point Tag O.C. °F	Explosive Limits % by Vol. in Air Lower	Explosive Limits % by Vol. in Air Upper	Solubility Parameter
1.1.1. TRICHLOROETHANE	100 0	1 0	1.0	6.0	124	-37 9	NONE	8.0	10.5	8 5
ETHYLENE DICHLORIDE	61 6	1 3	0 77	4.46	84	35 7	56[e]	6.2	15 9	9 8
METHYLENE CHLORIDE TECH	340	0.4	2.5	14.5	136	97	NONE	NONE	NONE	9.7
MONOCHLOROBENZENE	300[d]	5 4	0.19	1.07	133	45 6	82[e]	1 3	7 1	9 5
ORTHODICHLOROBENZENE	**0.348**	**38.0**	**0.03**	**0.15**	**240**	**—22**	**160**	**2.2**	**9.2**	**10.0**
PERCHLORETHYLENE	13.0	2 8	0.34	2 1	92	22 4	NONE	NONE	NONE	9 3
TRICHLORETHYLENE—Extract'n	59.0	1 3	0 77	4.46		86 4	NONE	8.0	10 5	9 3
TRICHLORETHYLENE—Degr'g	59.0	1 3	0 77	4 46	129	86 4	NONE	8 0	10 5	9 3
CC #49	345 0	1 3	0.77	4.46			NONE	NONE	NONE	9 6
SC #49 COLD DEGREASER		**30.0**	**0.03**	**0.17**						**8.0**
SC #149 COLD DEGREASER		10.0	0 1	0.5						8 3

Table 3.61: Dow Chemical Chlorinated Solvents *(23)*

Physical Properties of Chlorinated Solvents

PROPERTIES	SOLVENTS METHYLENE CHLORIDE	INHIBITED 1,1,1-TRICHLOROETHANE	TRICHLORO-ETHYLENE	PERCHLORO-ETHYLENE
Chemical Formula	CH_2Cl_2	$C_2H_3Cl_3$	C_2HCl_3	C_2Cl_4
Molecular Weight	84.9	133.4	131.4	165.8
Boiling Pt. @ 760 mm Hg	103.5°F (39.7°C)	165°F (74°C)	189°F (87°C)	250°F (121.1°C)
Freezing Point	-139°F (-95°C)	-34°F (-37°C)	-124°F (-86.7°C)	-9°F (-22.8°C)
Specific Gravity @ 25/25°C	1.32	1.32	1.456	1.619
Pounds per Gallon @ 25°C	10.98	10.97	12.11	13.47
Vapor Density (air = 1.00)	2.93	4.60	4.53	5.76
Specific Heat @ 25°C cal/g°C	0.283	0.259	0.226	0.209
Heat of Vaporization @ Boiling Point				
cal/g	78.9	56.7	56.4	50.1
BTU/lb	142	102	101.6	90.2
Refractive Index @ 25°C	1.421	1.434	1.474	1.503
Viscosity @ 25°C centipoises	0.41	0.79	0.54	0.84
Flash Point Tag Open Cup ASTM, Method D-1310	none	none	none	none
Tag Closed Cup ASTM, Method D-56	none	none	none	none
Solubility (g/100g) @ 25°C				
H_2O in solvent	0.17	0.05	0.04	0.0105
solvent in H_2O	1.70	0.07	0.10	0.015
Surface Tension (dynes/cm @ 25°C)	27.1	25.1	28.7	31.8
Kauri Butanol Value	136	124	129	90
Solvent-Water Azeotropic Boiling Point	100.6°F (38.1°C)	149°F (65°C)	164°F (73.3°C)	190°F (87.8°C)
Flammable Limits (volume % of solvent in air) @ 25°C				
Lower Limit	14	7.5	8.0	none
Upper Limit	22	12.5	9.2 (saturation)	none

(continued)

Table 3.61: (continued)

Relative Evaporation Rates†

n-Butyl acetate	1.0
Ethanol*	1.4
Perchloroethylene	1.5
Methyl alcohol	2.1
Trichloroethylene	3.0
Methyl ethyl ketone	3.9
1,1,1-Trichloroethane	4.6
Acetone	5.7
Methylene chloride	7.0

*95% Et OH, 5% H_2O
† Evaporation rates measured with respect to n-butyl acetate. Larger numbers reflect faster evaporation. As measured by ASTM D3539-76.

Methylene Chloride Compatibility with Plastics, Elastomers and Rubbers

	% Linear Swell	
Plastics	**Initial**	**After Drying**
Polypropylene (General Purpose Grade)	3.5	0
Polyethylene 3300 (High Density)	1.0	0
Polyethylene (Linear)	3.0	–0.5
Polyallomer (Ethylene Propylene Copolymer)	4.0	0
Acetate (Cellulose Acetate)	A.B	0
Butyrate (Cellulose Acetate Butyrate)	C	–
Propionate (Cellulose Acetate Propionate)	C	–
Brand of Elastomers and Rubbers		
Chardon 15093[a]	56.0	–0.5
Chardon 15096-2[a]	80.5	–3.0
Chardon 15120[a]	76.5	–2.5
Hycar 1000 x 132[c] (Acrylonitrile/butadiene high acrylonitrile content)	44.5	–3.0
Hycar 1014[c] (Buna N low acrylonitrile content)	55.0	–4.5
Thiokol 3000 FA[d] (Polysulfide Rubber)	52.5	–1.5
Thiokol 3600 ST-C[d]	50.0	–0.5
Thiokol E455[d]	64.0	–4.5
Dow Corning 94-002[b] (Fluorosilicone Rubber)	16.0	–2.0
Silastic LS-63[b] (Fluorosilicone Rubber)	16.5	0
Silastic S-6526[b] (Silicone Rubber)	34.5	–
Silastic 80[b] (Silicone Rubber)	24.0	–0.5
Silastic 675[b]	38.5	–0.5

Key: (Negative sign indicates sample decreased in size. Data to nearest 0.5%.)

a. Chardon Rubber Company
b. Dow Corning Corporation
c. B.F. Goodrich Chemical Company
d. Thiokol Chemical Company

A. Distorted and softened
B. Partially dissolved or disintegrated
C. Totally dissolved or disintegrated

(continued)

Table 3.61: (continued)

Solubilities of Resins, Waxes and Fats in Methylene Chloride

Material or Brand	Solubility†
Resins	
ABALYN – Resin esterified with glycerine	>100
ACRYLOID B-82 – Acrylic ester	>100
AMBEROL 801-XLT – Phenolic	>100
AMBEROL ST-137-X – Phenol-formaldehyde	>100
BAKELITE CKR-5254 – Phenolic	< 20
BECKACITE 1001 – Phenolic	>100
BECKACITE 1112 – Phenolic	>100
CUMAR W-1 – Paracumarone-indene	>100
D.E.N.* 438 – Epoxy novolac	>100
D.E.R.* 331 – Epoxy	>100
D.E.R. 332 – Epoxy	>100
D.E.R. 661 – Epoxy	>100
D.E.R. 664 – Epoxy	>100
D.E.R. 667 – Epoxy	>100
DOW Resin PS-3 – Polystyrene	>100
EPON 812 – Epoxy	>100
EPON 836 – Epoxy	>100
EPON 1004 – Epoxy	>100
EPON 1109 – Epoxy	>100
GENEPOXY 175 – Epoxy	>100
GENEPOXY M-180 – Epoxy	>100
GENEPOXY 190 – Epoxy	>100
GENEPOXY 525 – Epoxy	>100
GENEPOXY 925 – Epoxy	>100
GENEPOXY 1800 – Epoxy	>100
HERCOLYN – Resin esterified with glycerine	>100
Polymethyl methacrylate	>100
NEVINDENE RS – Cumarin indene	>100
Orange Shellac	< 1
PICCO 420 ES – Indene polymer	>100
PICCOLASTIC A-75 – Polystyrene	>100
PICCOLYTE S-85 – Polyterpene	>100
PICCOPALE 100 – Hydrocarbon	>100
Polyvinyl Chloride	< 1
Resin 276-V9 – Polyalkyl styrene	>100
Rosin (wood)	>100
SARAN** F-120 – Vinylidene chloride-acrylonitrile	< 1
SARAN F-220 – Vinylidene chloride-acrylonitrile	< 1
VELSICOL AE9 – ETO adducts	< 10
VERSAMIDE 940 – Polyamide	>100
VINYLITE AYAA – Vinyl acetate	>100
VINYLITE VYHH – Vinyl chloride acetate	< 50[1]
Oils & Resins	
ALINCO Z2 – Linseed oil	>100
Lanolin anhydrous	>100
OKO S-70 – Soybean oil	>100
Waxes	
Beeswax	< 5
Candelilla wax	< 1
Carnauba wax	< 1
Ceresin wax	< 1
Japan wax	< 1
Montan wax	< 1
Paraffin 47-49°C	< 15
White petrolatum	< 20
Fatty Acids & Derivatives	
Calcium Stearate	< 1
Potassium Oleate	< 1
Sodium Oleate	< 1
Stearic Acid	< 35
Miscellaneous	
D.C.R.-5061 – Silicone	>100
D.C.R.-5581 – Silicone	>100
PARLON S-5 – Chlorinated rubber	>100
PARLON S-20 – Chlorinated rubber	>100
PARLON S-300 – Chlorinated rubber	> 60[1]

[1]Too viscous for further addition.

*Trademark of The Dow Chemical Company

**Trademark of The Dow Chemical Company overseas

†Solubilities were determined by the incremental addition of solute to 100 grams of methylene chloride at room temperature. Solute was added in the following increments: 1 gram, 5 grams, 10 grams and so on in 5-gram steps up to a maximum of 100 grams. Thus a notation of <5 indicates that more than 1 gram but less than 5 grams of solute can be dissolved in 100 grams of methylene chloride. Similarly, a notation of <40 indicates that more than 35 but less than 40 grams of solute will dissolve. Where 100 grams of solute dissolve, the result is reported as >100. Resin solubilities were obtained on **uncured** material suitable for use in paints, adhesives, and coatings.

(continued)

Table 3.61: (continued)

Thermodynamic Properties of Methylene Chloride in the Ideal Gas State

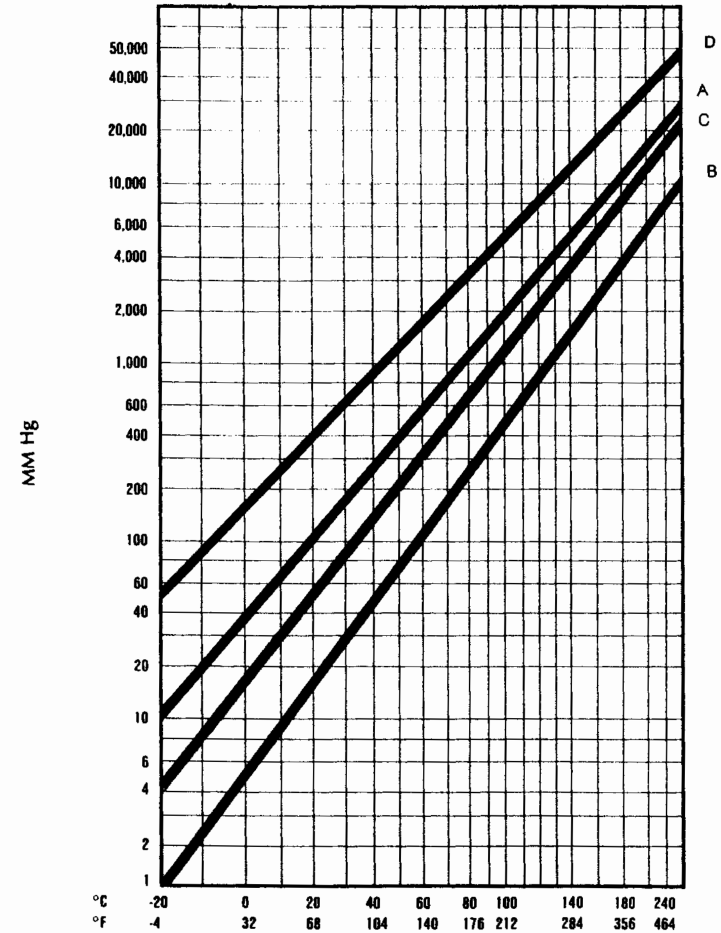
Temperature °C	Heat Capacity cal/(mol °C)	Enthalpy cal/mol	Entropy cal/(mol °C)
25	12.17	0	64.61
50	12.70	311	65.61
100	13.71	972	67.51
150	14.65	1,681	69.29
200	15.49	2,435	70.97
250	16.26	3,229	72.57
300	16.95	4,060	74.08
350	17.57	4,923	75.53
400	18.13	5,815	76.90
450	18.64	6,735	78.22
500	19.10	7,679	79.48
550	19.52	8,645	80.69
600	19.91	9,631	81.86
650	20.26	10,635	82.98
700	20.58	11,656	84.05
750	20.88	12,693	85.09

Thermodynamic Properties of Perchloroethylene

Temperature °C	Heat Capacity @ 1 atm cal/(mol °C)	Enthalpy 25°C = 0 cal/mol	Entropy cal/(mol °C)
27	22.9	46	76.8
77	24.3	1,226	80.5
127	25.4	2,466	83.8
177	26.3	3,756	86.8
227	27.0	5,086	89.6
277	27.6	6,451	92.2
327	28.1	7,841	94.7
377	28.5	9,256	96.9
427	28.9	10,691	99.1
477	29.2	12,141	101.1
527	29.5	13,611	103.0
577	29.7	15,091	104.0
627	29.9	16,581	106.4
677	30.1	18,081	108.1

Heat of formation @ 25°C = 17,700 cal/mol
Critical temperature = 352.1°C
Critical pressure = 45.5 atm
Critical density = 0.492 g/cc

Vapor Pressure of Chlorinated Solvents



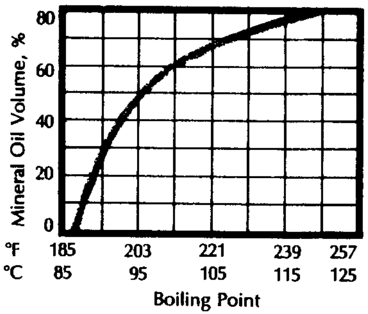
A Inhibited 1,1,1-Trichloroethane B Perchloroethylene C Trichloroethylene D Methylene Chloride

(continued)

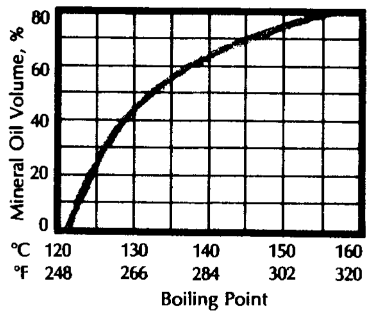
Table 3.61: (continued)

Boiling Temperatures of Chlorinated Solvents and Oil

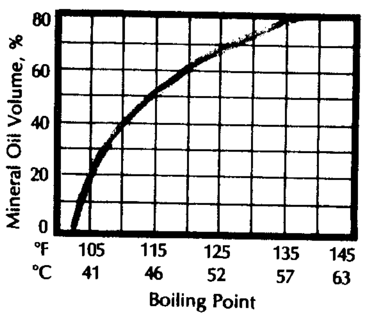
Trichloroethylene



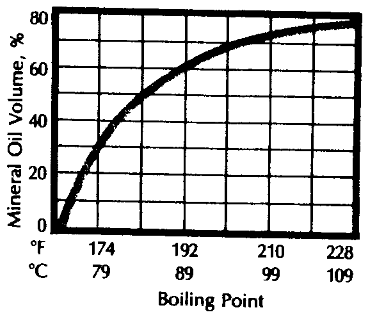
Perchloroethylene



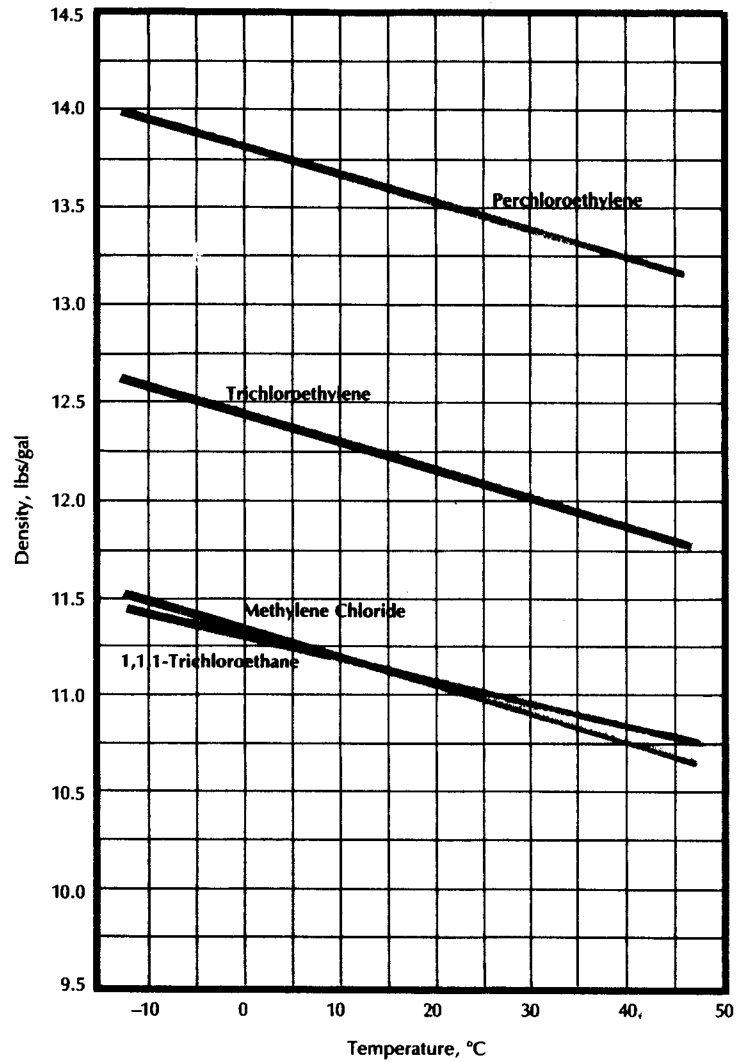
Methylene Chloride



Inhibited 1,1,1-Trichloroethane



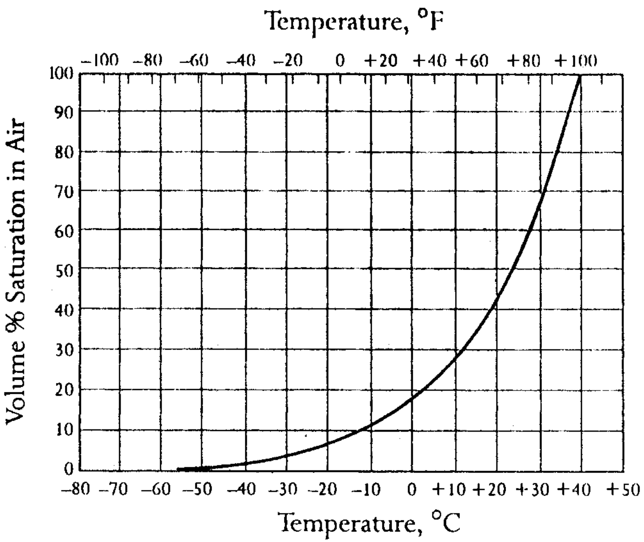
Density of Chlorinated Solvents as a Function of Temperature



(continued)

Table 3.61: (continued)

Dew Point of Methylene Chloride

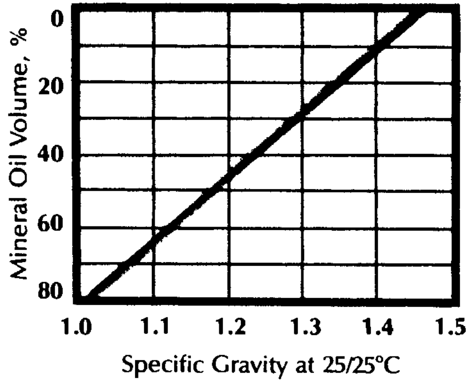


Methylene Chloride Flammability Data

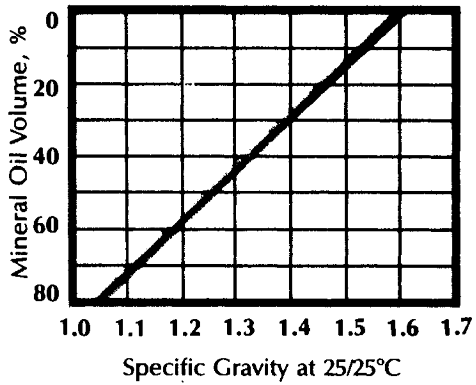
Flash point (Tag Open Cup ASTM D-1310)	None
Fire point (Tag Open Cup ASTM D-1310)	None
Initial thermal degradation	250 °F (120 °C)
Autoignition temperature	1033 °F (556 °C)
Flammable range	
% volume in air (25 °C) 10 kilowatt spark	14-22
% volume in oxygen (25 °C)	14-66

Specific Gravity Data

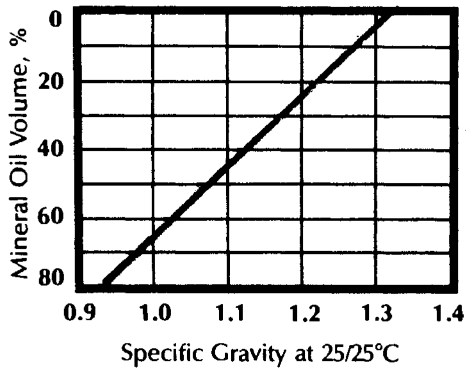
Trichloroethylene



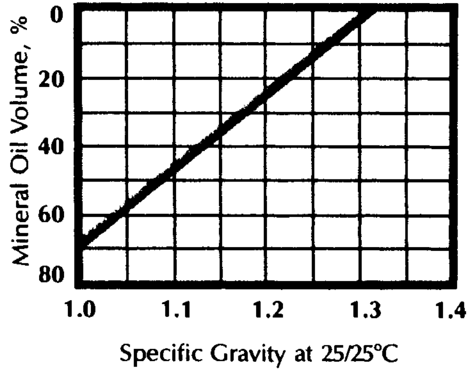
Perchloroethylene



Methylene Chloride



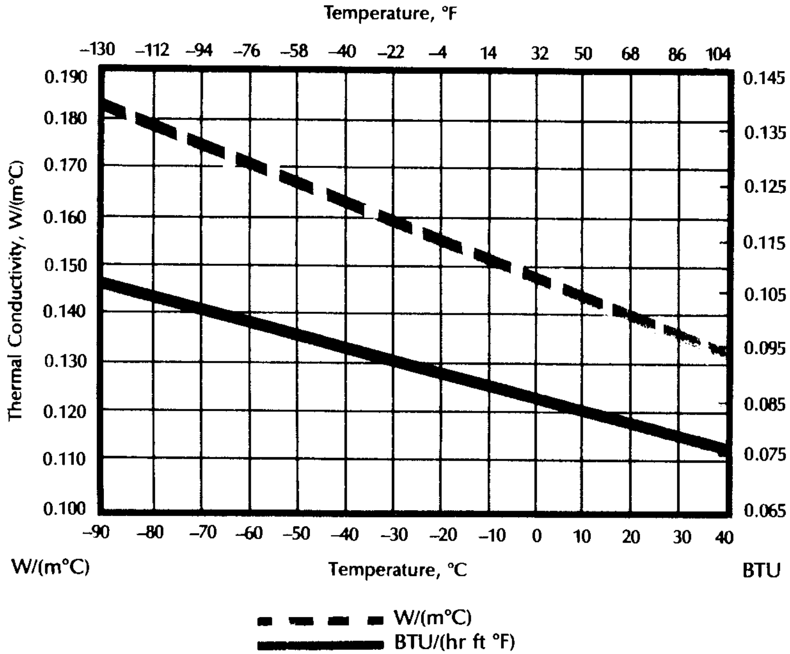
Inhibited 1,1,1-Trichloroethane



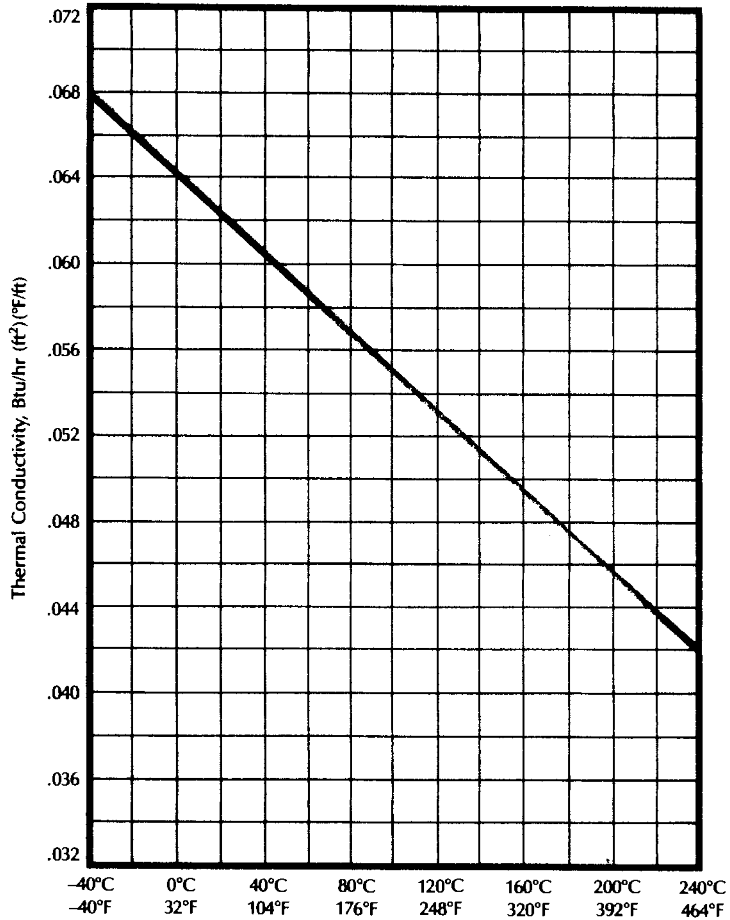
(continued)

Table 3.61: (continued

Thermal Conductivity vs Temperature of Methylene Chloride



Thermal Conductivity vs Temperature of Perchloroethylene



Solvency Power

Kauri butanol value	136
Solubility parameter (Cal/cc 25°C)	9.9
Hydrogen bonding parameter	2.2
Dipole moment (Debyes)	1.6

Relative Evaporation Rates†

n-Butyl acetate	1.0
Ethanol	1.6
Perchloroethylene	1.5
Methyl alcohol	1.8
Heptane	3.5
Trichloroethylene	3.1
Methyl ethyl ketone	3.9
1,1,1-Trichloroethane	4.5
Acetone	5.6
Methylene chloride	7.0

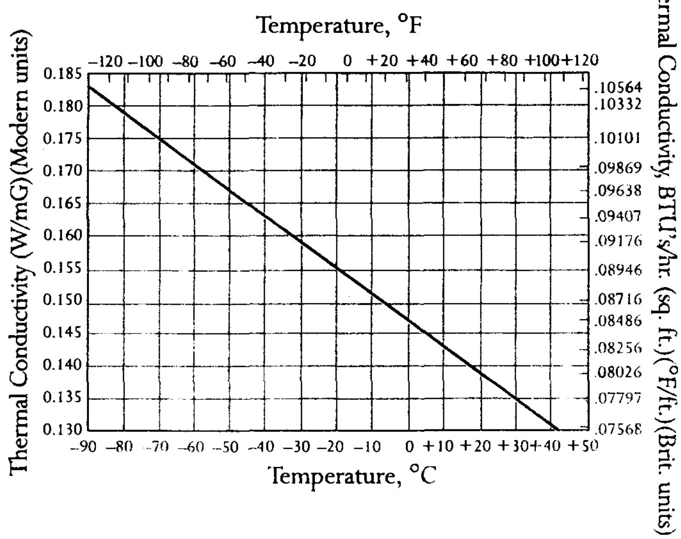
†Evaporation rates measured with respect to n-butyl acetate. Larger numbers reflect evaporation

Table 3.61: (continued)

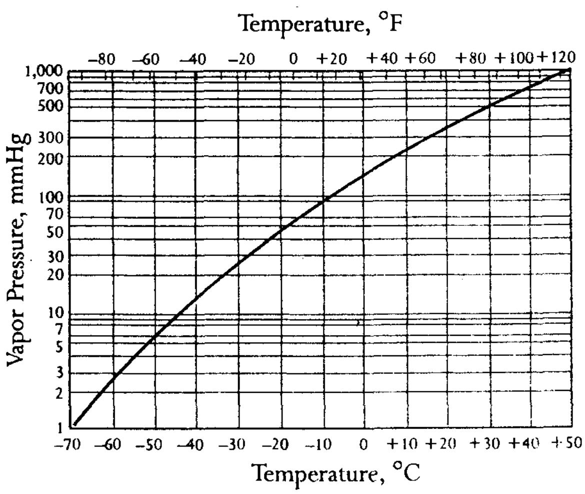
Blending Solvénts to Eliminate Flash Points

Family	Flammable Constituent Data Source	Flash Points (°F) –Tag Closed Tester Volume % Chlorinated Solvent 0	10	20	30	40	50
Alcohol	Ethanol	60	54	48	NF		
	n-Butanol	106	94	NF			
Ester	Butyl Acetate	84	81	76	NF		
	Ethyl Acetate	25	32	34	39	41	NF
Hydrocarbon	Heptane	21	23	21	22	NF	
	Octane	59	49	NF			
Ketone	Methyl Isobutyl Ketone	64	64	64	62	NF	

Thermal Conductivity vs. Temperature for Methylene Chloride



Vapor Pressure vs. Temperature for Methylene Chloride



Density vs. Temperature for Methylene Chloride

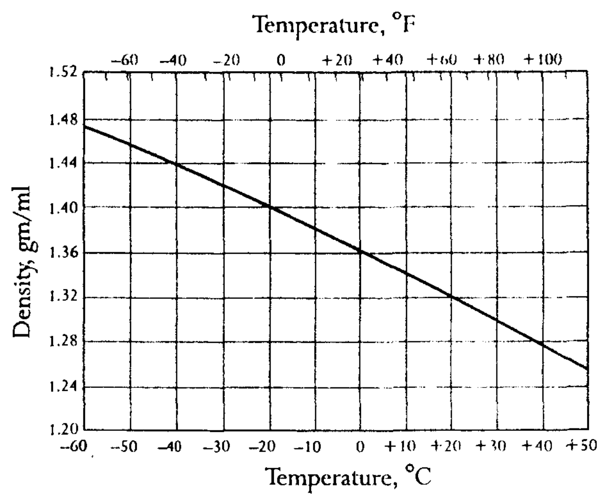
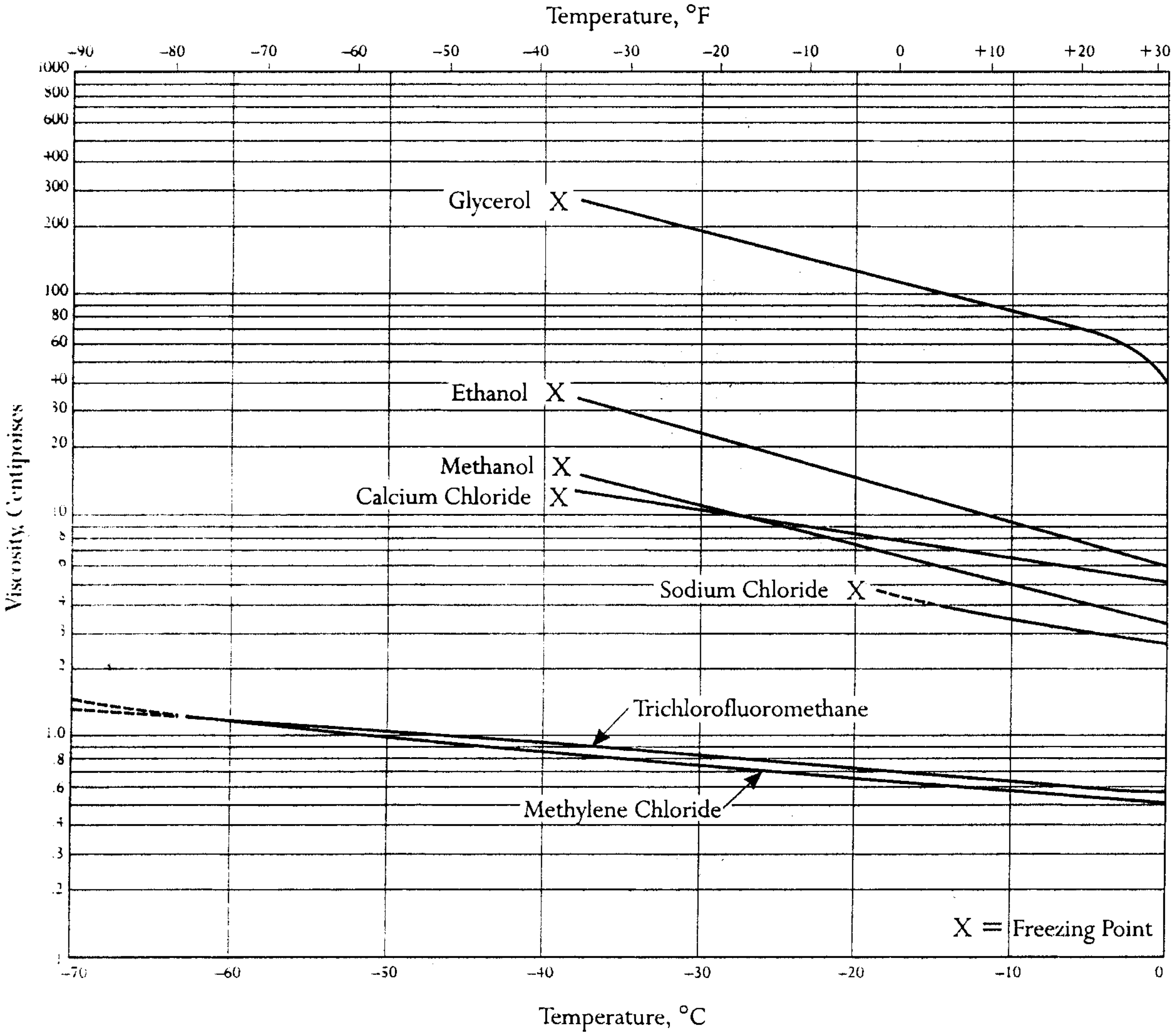


Table 3.61: (continued)

Viscosity Curves for Common Secondary Refrigerants



Glycerol	=	64.8% Wt. (Aqueous Solution)
Ethanol	=	56.8% Wt. (Aqueous Solution)
Calcium Chloride	=	29.0% Wt. (Aqueous Solution)
Methanol	=	38.4% Wt. (Aqueous Solution)
Sodium Chloride	=	21.0% Wt. (Aqueous Solution)
Trichlorofluoromethane	=	100% Wt.
Methylene Chloride	=	100% Wt.

Table 3.62: Vertrel Cleaning Agents *(11)*

Vertrel KCD-9547 Cleaning Agent

Introduction

Vertrel KCD-9547 is a proprietary azeotrope-like blend of Vertrel XF hydrofluorocarbon with trans-1,2-dichloroethylene and cyclopentane. It is ideally suited for use in vapor degreasing equipment to remove light oils, fingerprints, and particulate contaminants. Vertrel KCD-9547 is specially formulated to provide a high degree of compatibility with plastics, elastomers, and other nonferrous metals, such as in aerospace parts. Vertrel KCD-9547 is nonflammable, has "zero" ozone depletion potential, and has low global warming potential. It can replace CFC-113, 1,1,1-trichloroethane (1,1,1-TCA), hydrochlorofluorocarbons (HCFC), and perfluorocarbons (PFC) in many applications.

Physical Properties

Property*	Units	Vertrel® KCD-9547	CFC-113
Boiling Point	°C	37.2	47.6
	°F	99.0	117.6
Liquid Density	g/cc	1.29	1.56
	lb/gal	10.8	13.1
Vapor Pressure	mmHg	414	334
	psi	8.0	6.5
Surface Tension	dyn/cm	15.3	17.3
Freezing Point	°C	<-50	-35
	°F	<-58	-31
Heat of Vaporization at boiling point	cal/g	47	35
	Btu/lb	85	63
Heat Capacity at 20°C (68°F)	cal/g °C	0.21	0.21
	Btu/lb °F	0.21	0.21
Viscosity	cps	0.65	0.68

*At 25°C (77°F) except where indicated.

Density and Vapor Pressure Change with Temperature

Temperature, °C	(°F)	Density, g/cc	(lb/gal)	Vapor Pressure, mmHg	(psi)
0	(32)	1.34	(11.2)	129	(2.5)
10	(50)	1.32	(11.1)	228	(4.4)
20	(68)	1.30	(10.9)	336	(6.5)
25	(77)	1.29	(10.8)	414	(8.1)
30	(86)	1.27	(10.6)	517	(10.0)
40	(104)	1.25	(10.5)	776	(15.0)
50	(122)	1.23	(10.3)	1034	(20.0)
60	(140)	1.21	(10.1)	1396	(27.0)

Soils Cleaned with Vertrel® KCD-9547

Fingerprints	Other Synthetic Oils
Hydraulic Oils	Particulates
Light Mineral Oils	Vegetable Oils

Preliminary Plastic Compatibility Immersion: 15 min at boiling point (37°C [99°F])

Compatible	
Acetal	Polyimides
Epoxy	Polypropylene
HD Polyethylene	Polysulfone
Nylon	PVA
Phenolic	PVC
Polyester, PET and PBT	Teflon® TFE, FEP, PFA
Polyethylene	

Preliminary Elastomer Compatibility Immersion: 15 min at boiling point (37°C [99°F])

Compatible	
Buna-S*	Fluoroelastomers
Buna-N	Natural Rubber*
Butyl Rubber*	Neoprene
Chlorosulfonated PE	Polysulfide (e.g., Thiokol's FA)
EPDM (e.g., Nordel®)	Urethane

*Swelling, but with low extractables

Exposure Limits

Component	Limit, ppm	Type
Vertrel® XF	AEL 200	8- and 12-hr TWA
	400	Ceiling*
trans-1,2-dichloroethylene	TLV 200	8-hr TWA
Cyclopentane	TLV 600	8-hr TWA

AEL—DuPont's acceptable exposure limit.
TLV—Threshold limit value established by the American Conference of Government & Industrial Hygienists (ACGIH).
TWA—Time weighted average.
*A ceiling limit is the concentration that should not be exceeded during any part of the working day.

Vertrel® KCD-9547 Specifications

Vertrel® XF, %	65.0 ± 1.0
trans-1,2-dichloroethylene, %	20.0 ± 1.0
Cyclopentane, %	15.0 ± 2.0
Appearance	Clear, colorless
Nonvolatile Residue, ppm	10.0 max.
Moisture, ppm	<200

(continued)

Table 3.62: (continued)

Vertrel KCD-9548 and KCD-9550 Wipe Solvents

Introduction

Vertrel KCD-9548 and Vertrel KCD-9550 are two proprietary blends formulated as wipe solvents. Vertrel KCD-9548 is an azeotrope-like blend of Vertrel XF hydrofluorocarbon with cyclohexane and acetone, whereas Vertrel KCD-9550 is an azeotrope-like blend of Vertrel XF hydrofluorocarbon and acetone. Both solvents are ideally suited for use as a gross wipe solvent; however, Vertrel KCD-9548 has a slight VOC compared with zero VOC for Vertrel KCD-9550.

Physical Properties

Property*	Units	Vertrel® KCD-9548	Vertrel® KCD-9550
Boiling Point	°C	52.0	60.6
	°F	125.6	141.1
Liquid Density	g/cc	1.37	1.37
	lb/gal	11.5	11.5
Vapor Pressure	mmHg	186	191
	psi	3.6	3.7
Surface Tension	dyn/cm	15.6	15.6
Freezing Point	°C	<-50	<-50
	°F	<-80	<-80
Heat of Vaporization at boiling point	cal/g	43	46
	Btu/lb	77	83
Heat Capacity at 20°C (68°F)	cal/g °C	0.30	0.30
	Btu/lb °F	0.30	0.30
Viscosity	cps	0.64	0.62

*At 25°C (77°F) except where indicated.

Vertrel® KCD-9548 Specifications

Vertrel® XF, %	85.0 ± 1.0
Acetone, %	10.0 ± 1.0
Cyclohexane, %	5.0 ± 1.0
Appearance	Clear, Colorless
Nonvolatile Residue, ppm	10.0 max.
Moisture, ppm	<200

Exposure Limits

Component	Limit, ppm	Type
Vertrel® XF	AEL 200	8- and 12-hr TWA
	400	Ceiling*
Acetone	TLV 750	8-hr TWA
Cyclohexane	TLV 300	8-hr TWA

TLV —Threshold limit value established by the American Conference of Government & Industrial Hygienists (ACGIH).

TWA—Time weighted average.

*A ceiling limit is the concentration that should not be exceeded during any part of the working day.

Vertrel® KCD-9548 Density and Vapor Pressure Change with Temperature

Temperature, °C	(°F)	Density, g/cc	(lb/gal)	Vapor Pressure, mmHg	(psi)
0	(32)	1.42	(11.9)	52	(1.1)
10	(50)	1.40	(11.8)	98	(1.9)
20	(68)	1.38	(11.6)	155	(2.9)
25	(77)	1.37	(11.5)	186	(3.6)
30	(86)	1.36	(11.4)	248	(4.8)
40	(104)	1.34	(11.3)	362	(6.9)
50	(122)	1.32	(11.1)	569	(11.0)
60	(140)	1.30	(10.9)	776	(15.0)

Vertrel® KCD-9550 Density and Vapor Pressure Change with Temperature

Temperature, °C	(°F)	Density, g/cc	(lb/gal)	Vapor Pressure, mmHg	(psi)
0	(32)	1.42	(11.9)	52	(1.1)
10	(50)	1.40	(11.8)	98	(1.8)
20	(68)	1.38	(11.6)	155	(2.8)
25	(77)	1.37	(11.5)	186	(3.7)
30	(86)	1.36	(11.4)	248	(4.5)
40	(104)	1.34	(11.3)	362	(6.9)
50	(122)	1.32	(11.1)	569	(10.0)
60	(140)	1.30	(10.9)	776	(15.0)

Preliminary Elastomer Compatibility Immersion: 5 Minutes at Room Temperature 25°C (77°F)

Compatible	
Polysulfide (Thiokol's FA)	EPDM (Nordel®)
Silicone	Butyl Rubber
Chlorosulfonated PE	Natural Rubber
Urethane	Neoprene
Buna-S	Adiprene
Buna-N	Viton® A and Viton® B

Vertrel® KCD-9550 Specifications

Vertrel® XF, %	85.0 ± 1.0
Acetone, %	15.0 ± 1.0
Appearance	Clear, Colorless
Nonvolatile Residue, ppm	10.0 max.
Moisture, ppm	<200

Preliminary Plastic Compatibility Immersion: 5 Minutes at Room Temperature 25°C (77°F)

Compatible	
Acrylic	HD Polyethylene
Polyethylene	Epoxy
Polypropylene	Phenolic
Polycarbonate	Teflon® TFE, FEP, PFA
Polystyrene	Polyester, PET, PBT
PVA, PVC	Acetal
Polyimides	Polysulfone
Nylon	

(continued)

Table 3.62: (continued)

Vertrel MCA Cleaning Agent

Introduction

Vertrel MCA is a proprietary azeotrope of Vertrel XF hydrofluorocarbon with trans-1,2-dichloroethylene. It is ideally suited for use in vapor degreasing equipment. Its enhanced solvency power, compared to Vertrel XF alone, makes it particularly effective for precision and specialty cleaning applications in difficult soil situations. Vertrel MCA is nonflammable, has "zero" ozone depletion, and has low global warming potential. It can replace CFC-113, 1,1,1-trichloroethane (1,1,1-TCA), hydrochlorofluorocarbons (HCFCs), and perfluorocarbons (PFCs) in many applications.

Physical Properties

Property*	Unit	Vertrel® MCA	CFC-113
Boiling Point	°C (°F)	39 (102)	47.6 (117.6)
Liquid Density	g/cc	1.41	1.56
	lb/gal	11.8	13.1
Vapor Pressure	mmHg	464	334
	psia	9.0	6.5
Surface Tension	dyn/cm	15.2	17.3
Freezing Point	°C (°F)	<-50 (<-58)	-35 (-31)
Solubility of Water	wt%	0.065	0.011
Heat of Vaporization at Boiling Point	cal/g	43.3	35.1
	Btu/lb	77.9	63.1
Heat Capacity at 20°C (68°F)	cal/g-°C	0.27	0.21
	Btu/lb-°F	0.27	0.21
Viscosity	cPs	0.49	0.68

*At 25°C (77°F), except where indicated

Density and Vapor Pressure Change with Temperature

Temperature, °C (°F)	Density, g/cc (lb/g)	Vapor Pressure, mmHg (psia)
0 (32)	1.47 (12.3)	162 (3.1)
10 (50)	1.44 (12.0)	258 (5.0)
20 (68)	1.42 (11.8)	375 (7.3)
25 (77)	1.41 (11.8)	446 (9.0)
30 (86)	1.39 (11.6)	552 (10.7)
40 (104)	1.37 (11.4)	795 (15.4)
50 (122)	1.35 (11.3)	1111 (21.5)
60 (140)	1.33 (11.1)	1509 (29.2)

Soils Cleaned with Vertrel® MCA

Mineral Oils	Cutting Oils
Vacuum Oils	Stamping Oils
Waxes	Hydraulic Oils
Heavy Greases	Gear Oils

Preliminary Plastic Compatibility Immersion: 1 Week at 55°C (131°F)

Compatible	
Polyethylene	HD Polyethylene
Polypropylene	Epoxy
Nylon	Phenolic
Polyester, PET, and PBT	Teflon® TFE, FEP, PFA
Acetal	Polyimides
Require Additional Testing	
ABS	Polycarbonate
Acrylic	Polystyrene
Polyvinyl Chloride	Polyphenylene Oxide
Polysulfone	

Preliminary Elastomer Compatibility Immersion: 1 Week at 55°C (131°F)

Compatible	
Polysulfide (Thiokol FA)	EPDM (Nordel®)
Chlorosulfonated PE	Butyl Rubber*
Buna-S*	Natural Rubber*
Require Additional Testing	
Buna-N	Polychloroprene
Urethane	Silicone
Fluoroelastomers	

*Swelling, but with low extractables

Exposure Limits

Component	Limit, ppm		Type
Vertrel® XF	AEL[a]	200	8- and 12-hr TWA
		400	Ceiling[b]
trans-1,2-dichloroethylene	TLV[c]	200	8-hr TWA

[a] AEL is the DuPont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits that are lower than the AEL are in effect, such limits shall take precedence.

[b] A ceiling limit is the concentration that should not be exceeded during any part of the working day.

[c] TLV is the Threshold Limit Value established by the American Conference of Government Industrial Hygienists (ACGIH).

Vertrel® MCA Specifications

Vertrel® XF	62.0% ± 1.0*
trans-1,2-dichloroethylene	38.0% ± 1.0*
Appearance	Clear, Colorless
Nonvolatile Residue	10.0 ppm max.
Moisture	< 200 ppm

*Wt%

(continued)

Table 3.62: (continued)

Vertrel MCA Plus Cleaning Agent

Introduction

Vertrel MCA Plus is a proprietary azeotrope of Vertrel XF hydrofluorocarbon with trans-1,2-dichloroethylene and cyclopentane. It is ideally suited for use in vapor degreasing equipment for precision cleaning and specialty applications. Its enhanced solvency power makes it particularly effective in difficult soil situations. Vertrel MCA Plus is nonflammable, has "zero" ozone depletion, and has low global warming potential. It can replace CFC-113, 1,1,1-trichloroethane (1,1,1-TCA), hydrochlorofluorocarbons (HCFC), and perfluorocarbons (PFC) in many applications.

Physical Properties

Property*	Unit	Vertrel® MCA Plus	HCFC-141b	1,1,1 TCA	Freon® TF
Boiling Point	°C	37	32	74	48
	°F	99	90	165	118
Liquid Density	g/cc	1.28	1.24	1.31	1.56
	lb/gal	10.7	10.3	11.0	13.1
Vapor Pressure	mmHg	440	594	140	226
	psi	8.5	11.5	2.7	4.4
Surface Tension	dyne/cm	15.9	19.3	25.9	17.3
Freezing Point	°C	<-50	-103	<-50	-35
	°F	<-58	-154	<-58	-31
Heat of Vaporization	cal/g	55	53	57	35
at boiling point	Btu/lb	98	94	102	63
Heat Capacity	cal/g °C	0.22	0.25	0.26	0.22
at 20°C (68°F)	Btu/lb °F	0.22	0.25	0.26	0.22
Viscosity	cP	0.61	0.43	0.45	0.67
Flash Point		None	None	None	None

*At 25°C (77°F) except where indicated.

Density and Vapor Pressure Change with Temperature

Temperature, °C	(°F)	Density, g/cc	(lb/gal)	Vapor Pressure, mmHg	(psi)
0	(32)	1.33	(11.1)	124	(2.4)
10	(50)	1.31	(10.9)	222	(4.3)
20	(68)	1.29	(10.8)	321	(6.2)
25	(77)	1.28	(10.7)	440	(8.5)
30	(86)	1.26	(10.5)	517	(10.1)
40	(104)	1.24	(10.3)	776	(14.9)
50	(122)	1.21	(10.8)	1034	(19.9)
60	(140)	1.18	(9.83)	1396	(27.1)

Soils Cleaned with Vertrel® MCA Plus

Cutting Oils	Stamping Oils
Drawing Oils	Synthetic Oils (POE, POG, etc.)
Gear Oils	Vacuum Oils
Heavy Greases	Waxes
Hydraulic Oils	
Mineral Oils	

Plastic Compatibility Immersion: 15 min at 37°C (99°F)

Compatible	
Acetal	Polyimides
Epoxy	Polypropylene
HD Polyethylene	Polysulfone (e.g., GE's Ultem)
Nylon	PVA
Phenolic	PVC
Polyester, PET and PBT	Teflon® TFE, FEP, PFA
Polyethylene	

Elastomer Compatibility Immersion: 15 min at 37°C (99°F)

Compatible	
Buna-S*	Neoprene
Butyl Rubber*	Polysulfide (e.g., Thiokol's FA)
Chlorosulfonated PE	Polyurethane
EPDM (e.g., Nordel®)	Viton® A
Natural Rubber*	Viton® B

*Swelling, but with low extractables

Exposure Limits

Component	Limit, ppm	Type
Vertrel® XF	AEL 200	8- and 12-hr TWA
	400	Ceiling*
trans-1,2-dichloroethylene	TLV 200	8-hr TWA
Cyclopentane	TLV 600	8-hr TWA
Vertrel® MCA Plus	AEL 221	Calculated **
	400	Ceiling*

AEL—DuPont's acceptable exposure limit.

TLV—Threshold limit value established by the American Conference of Government & Industrial Hygienists (ACGIH).

TWA—Time weighted average.

*A ceiling limit is the concentration that should not be exceeded during any part of the working day.

**Calculated in accordance with ACGIH Formula for TLVs for mixtures.

Vertrel® MCA Plus Specifications

Vertrel® XF, %	46.0 ± 1.0
trans-1,2-dichloroethylene, %	40.0 ± 1.0
Cyclopentane, %	14.0 ± 2.0
Appearance	Clear, colorless
Nonvolatile Residue, ppm	10.0 max.
Moisture, ppm	<200

(continued)

Table 3.62: (continued)

Vertrel SMT Cleaning Agent

Introduction

Vertrel SMT is a proprietary azeotrope-like blend of Vertrel XF hydrofluorocarbon with trans-1,2-dichloroethylene and methanol. It is ideally suited for use in vapor degreasing equipment with solvency power for cleaning ionic soils and flux residues from electronic assemblies. It can also be used for precision and general industrial cleaning where this enhanced solvency is required. Vertrel SMT is nonflammable, has zero ozone depletion potential, and has low global warming potential. It can replace CFC-113, 1,1,1-trichloroethane (1,1,1-TCA), hydrochlorofluorocarbon (HCFC), and perfluorocarbon (PFC) fluids in many applications.

Physical Properties

Property*	Vertrel® SMT	Freon® TMS
Boiling Point, °C (°F)	37 (99)	39.7 (103.5)
Liquid Density, g/cc (lb/gal)	1.35 (11.3)	1.48 (12.3)
Vapor Pressure, mmHg (psia)	486 (9.4)	429 (8.3)
Surface Tension, dyn/cm	15.5	17.4
Freezing Point, °C (°F)	<–50 (<–58)	–55 (–66)
Solubility of Water, wt%	0.34	0.27
Heat of Vaporization at Boiling Point, cal/g (Btu/lb)	49.5 (89.1)	50.4 (90.7)
Heat Capacity at 20°C (68°F), cal/g·°C (Btu/lb·°F)	0.27 (0.27)	0.24 (0.24)
Viscosity, cPs	0.49	0.70

*At 25°C (77°F), except where indicated.

Density and Vapor Pressure Change with Temperature

Temperature, °C (°F)	Density, g/cc (lb/g)	Vapor Pressure, mmHg (psia)
0 (32)	1.41 (11.7)	169 (3.3)
10 (50)	1.38 (11.5)	265 (5.1)
20 (68)	1.36 (11.4)	397 (7.7)
25 (77)	1.35 (11.3)	486 (9.4)
30 (86)	1.34 (11.2)	581 (11.2)
40 (104)	1.31 (11.0)	839 (16.2)
50 (122)	1.29 (10.8)	1,192 (23.1)
60 (140)	1.27 (10.6)	1,627 (31.5)

Preliminary Elastomer Compatibility
Immersion: One Week at 55°C (131°F)

Compatible	
Polysulfide (Thiokol FA)	EPDM (Nordel®)
Chlorosulfonated PE	Butyl Rubber*
Buna-S*	Natural Rubber*
Require Additional Testing	
Buna-N	Polychloroprene
Urethane	Silicone
Fluoroelastomers	

*Swelling, but with low extractables

Preliminary Plastic Compatibility
Immersion: One Week at 55°C (131°F)

Compatible	
Polyethylene	HD Polyethylene
Polypropylene	Epoxy
Nylon	Phenolic
Polyester, PET, and PBT	Teflon® TFE, FEP, PFA
Acetal	Polyimides
Require Additional Testing	
ABS	Polycarbonate
Acrylic	Polystyrene
Polyvinyl Chloride	Polyphenylene Oxide
Polysulfone	

Exposure Limits

Component	Limit, ppm		Type
Vertrel® XF	AEL[a]	200	8- and 12-hr TWA
		400	Ceiling[d]
trans-1,2-dichloroethylene	TLV[b]	200	8-hr TWA
Methanol	TLV[b]	200	8-hr TWA
	STEL[c]	250	
Stabilizer	TLV[b]	20	8-hr TWA

[a] AEL is the DuPont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits that are lower than the AEL are in effect, such limits shall take precedence.

[b] TLV is the Threshold Limit Value established by the American Conference of Government Industrial Hygienists (ACGIH).

[c] STEL is short-term exposure limit. A STEL is the concentration to which workers can be exposed continuously for a short period of time, usually 15 min, without suffering from acute effects, e.g., irritation.

[d] A ceiling limit is the concentration that should not be exceeded during any part of the working day.

Vertrel® SMT Specifications

Vertrel® XF	50.5% ± 1.0*
trans-1,2-dichloroethylene	43.0% ± 1.0
Methanol	6.0% ± 0.3
Stabilizer	0.5% ± 0.1
Appearance	Clear, Colorless
Nonvolatile Residue	10.0 ppm max.
Moisture	<200 ppm

*Wt%

(continued)

Table 3.62: (continued)

Vertrel XMS Cleaning Agent

Introduction

Vertrel XMS is a proprietary azeotrope-like blend of Vertrel XF hydrofluorocarbon with trans-1,2-dichloroethylene, cyclopentane, and methanol. It is ideally suited for use in vapor degreasing equipment with solvency power for cleaning ionic soils and flux residues from electronic assemblies.

Physical Properties

Property (at 25°C)	Unit	Vertrel® XMS	Freon® TMS	HCFC-141b with MeOH
Boiling Point	°C	36	40	29
	°F	96	104	85
Liquid Density	g/cc	1.22	1.48	1.22
	lb/gal	10.2	12.3	10.1
Vapor Pressure	mmHg	465	429	527
	psi	9.0	8.3	10.2
Surface Tension	dyne/cm	15.9	17.4	18.5
Freezing Point	°C	<-50	-55	<-103
	°F	<-58	-67	<-154
Heat of Vaporization	cal/g	61	50	62
at boiling point	Btu/lb	110	91	111
Heat Capacity	cal/g °C	0.24	0.24	0.26
at 20°C (68°F)	Btu/lb °F	0.24	0.24	0.26
Viscosity	cP	0.65	0.7	0.45
Flash Point		None	None	None

*At 25°C (77°F) except where indicated.

Exposure Limits

Component	Limit, ppm	Type
Vertrel® XF	AEL 200	8- and 12-hr TWA
	400	Ceiling*
trans-1,2-dichloroethylene	TLV 200	8-hr TWA
Cyclopentane	TLV 600	8-hr TWA
Methanol	TLV200	8-hr TWA
Vertrel® XMS	AEL 210	Calculated**
	400	Ceiling*

AEL—DuPont's acceptable exposure limit.

TLV—Threshold limit value established by the American Conference of Government & Industrial Hygienists (ACGIH).

TWA—Time weighted average.

*A ceiling limit is the concentration that should not be exceeded during any part of the working day.

**Calculated in accordance with ACGIH Formula for TLVs for mixtures.

Vertrel® XMS Specifications

Vertrel® XF, %	54.5 ± 1.0
trans-1,2-dichloroethylene, %	25.0 ± 1.0
Cyclopentane, %	14.0 ± 2.0
Methanol, %	6.0 ± 0.3
Inerting Agent, %	0.5 ± 0.1
Appearance	Clear, colorless
Nonvolatile Residue, ppm	10.0 max.
Moisture, ppm	<200

Density and Vapor Pressure Change with Temperature

Temperature, °C	(°F)	Density, g/cc	(lb/gal)	Vapor Pressure, mmHg	(psi)
0	(32)	1.27	(10.6)	155	(3.1)
10	(50)	1.25	(10.4)	259	(4.9)
20	(68)	1.23	(10.3)	414	(8.1)
25	(77)	1.22	(10.2)	465	(9.2)
30	(86)	1.21	(10.1)	620	(12.1)
40	(104)	1.19	(9.9)	931	(17.9)
50	(122)	1.17	(9.8)	1241	(23.7)
60	(140)	1.15	(9.6)	1706	(33.1)

Plastic Compatibility Immersion: 15 min at boiling point of Vertrel® XMS (35.5°C [96°F])

Compatible	
Acetal	Polyimides
Epoxy	Polypropylene
HD polyethylene	Polysulfone (e.g., GE's Ultem)
Nylon	PVA
Phenolic	PVC
Polyester, PET and PBT	Teflon® TFE, FEP, PFA
Polyethylene	

Elastomer Compatibility Immersion: 15 min at boiling point of Vertrel® XMS (35.5°C [96°F])

Compatible	
Buna-S*	Neoprene
Butyl Rubber*	Polysulfide (e.g., Thiokol's FA)
Chlorosulfonated PE	Polyurethane
EPDM (e.g., Nordel®)	Viton® A
Natural Rubber*	Viton® B

*Swelling, but with low extractables

(continued)

Table 3.62: (continued)

Vertrel XF Specialty Fluid

Introduction

Vertrel XF is a proprietary hydrofluorocarbon fluid with "zero" ozone depletion and a low global warming potential ideally suited for use in vapor degreasing equipment for cleaning, rinsing, and drying. It can replace current hydrochlorofluorocarbon (HCFC) and perfluorocarbon (PFC) fluids in most applications. Unique physical properties include a higher boiling point and lower surface tension compared to CFC-113. This combined with non-flammability, chemical and thermal stability, low toxicity, and ease of recovery by distillation make Vertrel XF ideal for a broad range of applications. Solvency is more selective than CFC-113, but can be enhanced by use of appropriate azeotropes and blends with alcohols.

Physical Properties

Property*	Vertrel® XF	CFC-113
Molecular Weight	252	187
Boiling Point, °C (°F)	55 (130)	47.6 (117.6)
Surface Tension, dyn/cm	14.1	17.3
Liquid Density, g/cc (lb/gal)	1.58 (13.2)	1.56 (13.1)
Freezing Point, °C (°F)	-80 (-112)	-35 (-31)
Solubility in Water, ppm	140	170
of Water, ppm	490	110
Critical Temperature, °C (°F)	181 (357)	214 (417)
Critical Pressure, psia (atm)	331.9 (22.6)	495 (33.7)
Critical Volume, cc/mol	433	325

*At 25°C (77°F), except where indicated.

Environmental Properties

Class:	HFC	CFC
Property	Vertrel® XF	CFC-113
Formula	$C_5H_2F_{10}$	$C_2Cl_3F_3$
Flash Point	None	None
Flammable Range in Air	None	None
Atmospheric Lifetime, yr	20.8	100
Ozone Depletion Potential (ODP)	0.0	0.8
Global Warming Potential (HGWP)	0.25	1.35

Heat Transfer Properties

Property*	Vertrel® XF
Heat of Vaporization (at boiling point), cal/g (Btu/lb)	31.0 (55.7)
Specific Heat at 20°C (68°F), cal/g·°C (Btu/lb·°F)	0.27 (0.27)
Vapor Pressure, mmHg (psia)	226 (4.4)
Viscosity, cPs	0.67

*At 25°C (77°F), except where indicated.

Density and Vapor Pressure Change with Temperature

Temperature, °C (°F)	Density, g/cc (lb/g)	Vapor Pressure, mmHg (psia)
-20 (-4)	1.70 (14.2)	16 (0.3)
-10 (14)	1.68 (14.0)	36 (0.7)
0 (32)	1.66 (13.8)	62 (1.2)
10 (50)	1.62 (13.5)	109 (2.1)
20 (68)	1.60 (13.3)	176 (3.4)
30 (86)	1.57 (13.1)	284 (5.5)
40 (104)	1.55 (12.9)	434 (8.4)
50 (122)	1.51 (12.6)	641 (12.4)
60 (140)	1.49 (12.4)	921 (17.8)
70 (158)	1.46 (12.2)	1288 (24.9)
80 (176)	1.43 (11.9)	1753 (33.9)
90 (194)	1.40 (11.7)	2343 (45.3)
100 (212)	1.38 (11.5)	3072 (59.4)
110 (230)	1.34 (11.2)	3961 (76.6)
120 (248)	1.32 (11.0)	5032 (97.3)
130 (266)	1.30 (10.8)	6309 (122.0)

Vertrel® XF Azeotropes

Vertrel®	XF With	Boiling Point, °C (°F)
XM	Methanol	46 (115)
XE	Ethanol	52 (126)
MCA	*trans*-1,2-dichloroethylene	39 (102)
SMT	*trans*-1,2-dichloroethylene and Methanol	37 (99)

Vertrel® XF Solvating Agents

Vertrel® XF Solvating Agents
Dibasic Esters (DBE)
Diisobutyl DBE
Methyl Decanoate
Isopropyl Myristate
N-Methyl-2-Pyrrolidone (NMP)
Tetrahydrofurfuryl Alcohol (THFA)
Aliphatic Hydrocarbons
Aliphatic Alcohols

(continued)

Table 3.62: (continued)

Plastic Compatibility Immersion: Two Weeks at 50°C (122°F)

Plastic	Common Brand Name	Rating	Weight Gain, %
HDPE	"Alathon"	0	0.3
PP	"Tenite"	0	0.5
PS	"Styron"	0	0.3
PVC		0	0.1
CPVC		0	0.1
PTFE	Teflon®	1[a]	3.5
ETFE	Tefzel®	1	1.4
PVDF	"Kynar"	0	0.4
Ionomer	Surlyn®	0	0.5
Acrylic	Lucite®	2	—[b]
ABS	"Kralastic"	0	0.0
Phenolic		0	0.0
Cellulosic	"Ethocel"	1[c]	4.7
Epoxy		0	0.0
Acetal	Delrin®	0	0.2
PPO	"Noryl"	0	0.2
PEK	"Ultrapek"	0	–0.1
PEEK	"Victrex"	0	–0.1
PET	Rynite®	0	0.2
PBT	"Valox"	0	0.0
Polyarylate	Arylon®	0	0.0
LCP		0	0.1
Polyimide			
A	Vespel®	0	0.0
PB	"Ultem"	0	0.1
PAI	"Torlon"	0	0.0
PPS	"Rython"	1	2.7
Polysulfone	"Udel"	0	–0.1
Polyaryl Sulfone	"Rydel"	0	–0.1

Rating	Physical Change
0—Compatible	[a]More Flexible
1—Borderline	[b]Sample Dissolved
2—Incompatible	[c]Some Extraction

Elastomer Compatibility Immersion, Sealed Tubes: Two Weeks at 50°C (122°F)

Elastomer	Rating	Linear Swell, %	Units Hardness Change
Natural Rubber	0	–0.6	–1
Butyl Rubber	0	1.0	–1
Nordel® RPDM	0	–1.0	–2
Neoprene CR	0	0.2	1
SBR	0	0.7	0
Nitrile Rubber			
NBR	0	–0.6	2
NHBR	0	3.9	–8
Vamac® EA	2*	13.9	–12
Hypalon® CSM	0	1.3	0
Fluoroelastomer			
Viton® A	2	17.3	–14
Viton® B	2	22.8	–34
Zalak®	2*	13.7	–13
Kalrez®	2	21.6	–20
Fluorinated Silicone	2	14.1	–11
Silicone	0	0.5	–4
Epichlorohydrin			
Homopolymer	0	–0.5	1
Copolymer	0	0.0	2
"Adiprene" U	1*	2.7	–2
FA Polysulfide	0	1.5	0
Thermoplastic			
Alcryn®	2*	–1.2	13
"Santoprene"	0	0.1	0
"Geoplast"	1*	–0.5	–3
Hytrel® Polyester	0	0.3	0

Rating: 0—Compatible; 1—Borderline; 2—Incompatible
*Noticeable extraction affecting rating

Vertrel® XF Specifications

Fluoropentanes	99.9% min.
Appearance	Clear, Colorless
Nonvolatile Residue (NVR)	2.0 ppm max.
Moisture	<50 ppm
Acidity, mg KOH/g	0.01 max.

Exposure Limits

Component	Limit, ppm		Type
Vertrel® XF	AEL[a]	200	8- and 12-hr TWA
		400	Ceiling[b]

[a] AEL is the DuPont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits that are lower than the AEL are in effect, such limits shall take precedence.
[b] A ceiling limit is the concentration that should not be exceeded during any part of the working day.

(continued)

Table 3.62: (continued)

Vertrel XSi Cleaning Agent

Introduction

Vertrel XSi is a proprietary blend of Vertrel XF hydrofluorocarbon and hexamethyldisiloxane. It is ideally suited for use in medical applications as a solvent for cleaning or depositing of silicone oil-based lubricants. It is also used as a swelling media for silicone rubber tubing.

Physical Properties

Property (at 25°C)	Unit	Vertrel® XSi	Freon® TF	HCFC-141b
Boiling Point	°C	57	48	32
	°F	134	118	90
Liquid Density	g/cc	1.17	1.56	1.24
	lb/gal	9.8	13.1	10.3
Vapor Pressure	mmHg	135	226	594
	psi	2.6	4.4	11.5
Surface Tension	dyne/cm	14.0	17.3	19.3
Freezing Point	°C	<–50	–35	–103
	°F	<–80	–31	–154
Heat of Vaporization at boiling point	cal/g	38	35	53
	Btu/lb	69	63	94
Heat Capacity at 20°C (68°F)	cal/g °C	N/A	0.22	0.25
	Btu/lb °F	N/A	0.22	0.25
Viscosity	cP	0.60	0.67	0.43
Flash Point		None	None	None

*At 25°C (77°F) except where indicated.

Swelling of Polysilicone Tubing

Test	Vertrel® XSi	Freon® TF	Hexane
At Room Temperature			
% Change in Width	15	16	23
% Change in Weight	60	133	83
At Boiling Point*			
% Change in Width	20	20	24
% Change in Weight	64	144	63

*47°C (117°F) for Freon® TF; 54°C (129°F) for Vertrel® KCD-XSi; 68°C (154°F) for Hexane

Plastic Compatibility
Immersion: 15 min in Vertrel® XSi at Boiling Point 56.6°C (133.9°F)

Compatible	
Polyethylene	HD polyethylene
Polypropylene	Epoxy
Nylon	Phenolic
Polyester, PET and PBT	Teflon® TFE, FEP, PFA
Acetal	Polyimides
PVC	Polysulfone (e.g., GE's Ultem)
Polycarbonate	Polyurethane

Vertrel® XSi Specifications

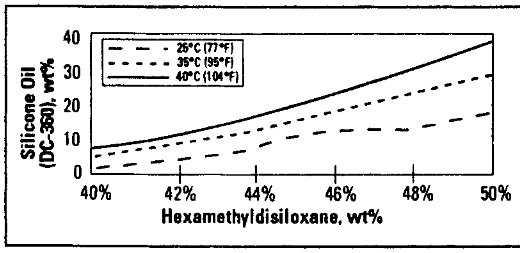
Vertrel® XF, %	57.0 ± 1.0
Hexamethyldisiloxane, %	43.0 ± 1.0
Appearance	Clear, Colorless
Nonvolatile Residue, ppm	10.0 max.
Moisture, ppm	<200

Solubility of Typical Silicone Fluids in Vertrel® XSi at Room Temperature (% Oil Loading in Solvent)

Oil	Vertrel® XSi	Freon® TF	Hexane
DC-200*	14	19	25
DC-360*	21	24	46
DC-550*	33	39	58
DC-1107*	45	51	65
NuSil Med 4159	28	29	31

*As manufactured by Dow Corning.

Solubility of Silicone Fluid (DC-360) in a Blend of Vertrel® XF + Hexamethyldisiloxane



Elastomer Compatibility
Immersion: 15 min in Vertrel® XSi at Boiling Point 56.6°C (133.9°F)

Compatible	
Polysulfide (e.g., Thiokol's FA)	EPDM (Nordel®)
Chlorosulfonated PE	Butyl Rubber*
Buna-S*	Natural Rubber*
Polyurethane	Neoprene
Viton® A	Viton® B

*Swelling, but with low extractable

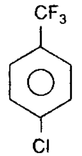
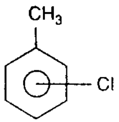
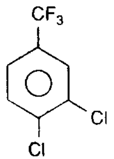
Exposure Limits

Component	Limit, ppm	Type
Vertrel® XF	AEL 200	8- and 12-hr TWA
	400	Ceiling*
Hexamethyl-disiloxane	IHG 200	8-hr TWA
Vertrel® XSi	AEL 200	Calculated**
	400	Ceiling*

AEL—DuPont's acceptable exposure limit.
IHG —Industrial Hygiene Guidelines.
TWA—Time weighted average.
*A ceiling limit is the concentration that should not be exceeded during any part of the working day.
**Calculated in accordance with ACGIH Formula for TLVs for mixtures.

Table 3.63: Occidental Chemical (OXSOL Solvents) *(27)*

Pure OXSOL Products *(27)*

OXSOL PRODUCT	HOW WILL YOU USE IT?		WHY?
OXSOL 100 100% Parachlorobenzotrifluoride (PCBTF) 	• To clean metal, plastics, electronics, and glass. • To dissolve resins in paints, coatings, inks, adhesives, and other resin applications. • To dilute for viscosity adjustment, for easy application.	• To carry active ingredients in aerosols. • As a reaction medium in the chemical, agricultural, and pharmaceutical industries. • As a drying agent for metals and plastics.	• To reduce or eliminate VOCs*. • To reduce or eliminate HAPs** • For selective solvency. • For its moderate evaporation rates. • For its high stability. • It is recyclable. • For high purity, low residue. • For classical solvent performance. • It is not miscible with water.
OXSOL 10 100% Monochlorotoluene (MCT) 	• As an aggressive solvent in formulations designed to remove paint and polymeric coatings. • As a cleanup solvent in the painting, coating, and printing industries. • As an additive to dissolve sludge in heavy fuels, asphalt, and coke applications.	• To carry inks and dyes in printing and textile production. • In heavy duty industrial and consumer cleaning products. • As an inert carrier for FIFRA*** regulated applications.	• For its low cost. • To reduce or eliminate HAPs. • For its aggressive solvency. • When a slow evaporation rate is needed. • No stabilizers are required. • It is recyclable. • It is approved as FIFRA*** inert.
OXSOL 1000 100% 3,4-Dichlorobenzotrifluoride (3,4-DCBTF) 	• In precision cleaning applications, when a high flashpoint is required. • As a stable solvent where contact with oxidizing media may occur. • As a stable high flash heat transfer medium.	• As a stable reaction medium. • As an adsorption medium for chlorine and oxygen. • In agricultural and pharmaceutical applications, as an extraction medium.	• For its high flashpoint (170°). • For its slow evaporation rate. • For its low reactivity. • For selective solvency. • It is exceptionally stable. • Where high purity and low residue are required. • To reduce or eliminate HAPs.

* Volatile Organic Compounds are regulated by *Title I* of the Clean Air Act of 1990.
** Hazardous Air Pollutants are regulated by *Title III* of the Clean Air Act of 1990.
*** Federal Insecticide Fungicide Rodenticide Act.

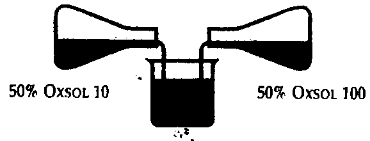
(continued)

Table 3.63: (continued)

Blended OXSOL Products *(27)*

Combustible Blend

OXSOL BLEND | **HOW CAN YOU USE IT?** | **WHY?**



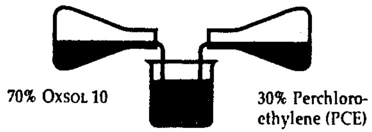
OXSOL 550

How can you use it?
- To dissolve resins in paints, coatings, inks, adhesives, and other resin applications.

Why?
- To eliminate HAPs.
- To reduce VOC (55%).
- For moderate solvency.
- For slow to moderate evaporation.
- For economy.

Non-Flammable Blends

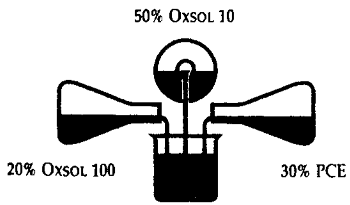
OXSOL BLEND | **HOW CAN YOU USE IT?** | **WHY?**



OXSOL 73

How can you use it?
- General purpose heavy duty cleaning.

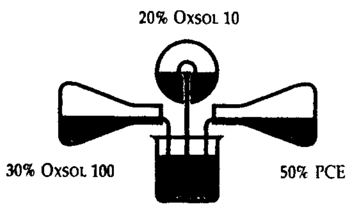
Why?
- To reduce HAPs (61%).
- For a low-cost, aggressive solvent.
- For non-flammability.
- To minimize worker exposure to PCE.
- For slow evaporation.



OXSOL 253

How can you use it?
- General purpose heavy duty cleaning.

Why?
- To reduce VOCs (21%).
- To reduce HAPs (37%).
- For a low-cost, aggressive solvent.
- For non-flammability.
- To minimize worker exposure to PCE.
- For slow to moderate evaporation.



OXSOL 325

How can you use it?
- Spray and wipe cleaning applications.

Why?
- To reduce VOCs (28%).
- To reduce HAPs (44%).
- For non-flammability.
- To minimize worker exposure to PCE.
- For fast evaporation (fastest of all Oxsol blends).

(continued)

Table 3.63: (continued)

Property Comparison

Product	Evaporation Rate[a]	Flash Point (°F)	Kauri Butanol Value	Solubility Parameter $(cal/cm^3)^{1/2}$	Boiling Point (°C)	Density (lbs/gal 20°C)
OXSOL 100	0.9	109	64	8.63	139	11.2
OXSOL 1000	0.2	170	69	8.89	174	12.3
OXSOL 10	0.4 - 0.8	123	110	9.6	159 - 162	9
OXSOL 550	0.7	113	92	8.93	142 - 159	10.0
OXSOL 73	0.6	None[b]	114	9.11	129 - 158	10.3
OXSOL 253	0.6	None[b]	109	9.94	127 - 159	10.7
OXSOL 325	1.2	None[b]	100	8.81	121 - 155	11.8
Methylene chloride	14.5	None	136	9.9	40	11
Perchloroethylene	1.5 - 2.59	None	90	9.8	121	13.5
Trichloroethylene	6.39	None	130	9.3	87	12.1
1,1,1-Trichloroethane[e]	6	None	124	8.9	74	11
CFC 113[d,e]	21	None	31	7.2	48	13.1
Dibasic ester	0.009	212	na[c]	9.2	210 - 215	7.3
d-Limonene	0.1	118	60	—	178	7.0
Toluene	2.0	40 - 45	105	8.9	111	7.2
Xylene	0.77 - 0.9	85	98	9.9	135 - 143	7.2
Acetone	6.1	0	na	9.8	56	6.6

[a] N-butyl acetate = 1 @ 25°C
[b] No flash to boiling using Cleveland closed cup apparatus
[c] Not applicable for oxygen containing compounds
[d] 1,1,2-trichloro-1,2,2-trifluoroethane
[e] Ozone depleting chemical

Regulatory Features Comparison (as of 1/1/96)

Product	Exempt from VOC Regulations	SARA Title III Reportable	Suspected Animal Carcinogen	Hazardous Air Pollutant
OXSOL 100	Yes	No	No	No
OXSOL 1000	No	No	No	No
OXSOL 10	No	No	No	No
OXSOL 550	Partial	No	No	No
OXSOL 73	No	Yes	Yes	Partial
OXSOL 253	Partial	Yes	Yes	Partial
OXSOL 325	Partial	Yes	Yes	Partial
Methylene chloride	Yes	Yes	Yes	Yes
Perchloroethylene	No	Yes	Yes	Yes
Trichloroethylene	No	Yes	No	Yes
1,1,1-Trichloroethane[1]	Yes	Yes	No	Yes
CFC 113[1,2]	Yes	Yes	No	No
Dibasic ester	No	No	No	No
d-Limonene	No	No	Yes	No
Toluene	No	Yes	No	Yes
Xylene	No	Yes	No	Yes
Acetone	Yes	No	No	No

[1] Ozone depleting chemical
[2] 1,1,2-trichloro-1,2,2-trifluoroethane

(continued)

Table 3.63: (continued)

Sales Specification

OXSOL® 10

Monochlorotoluenes

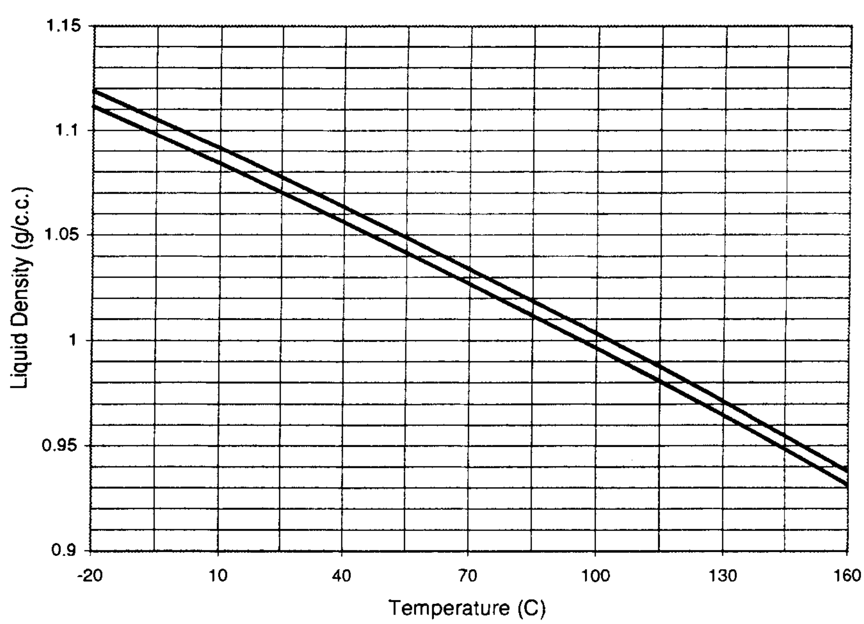
Specifications

Appearance	Clear, Free of suspended matter
Color, APHA	25 Max.
Monochlorotoluene	99.5% Min.
Toluene	0.4% Max.

Typical Physical Properties

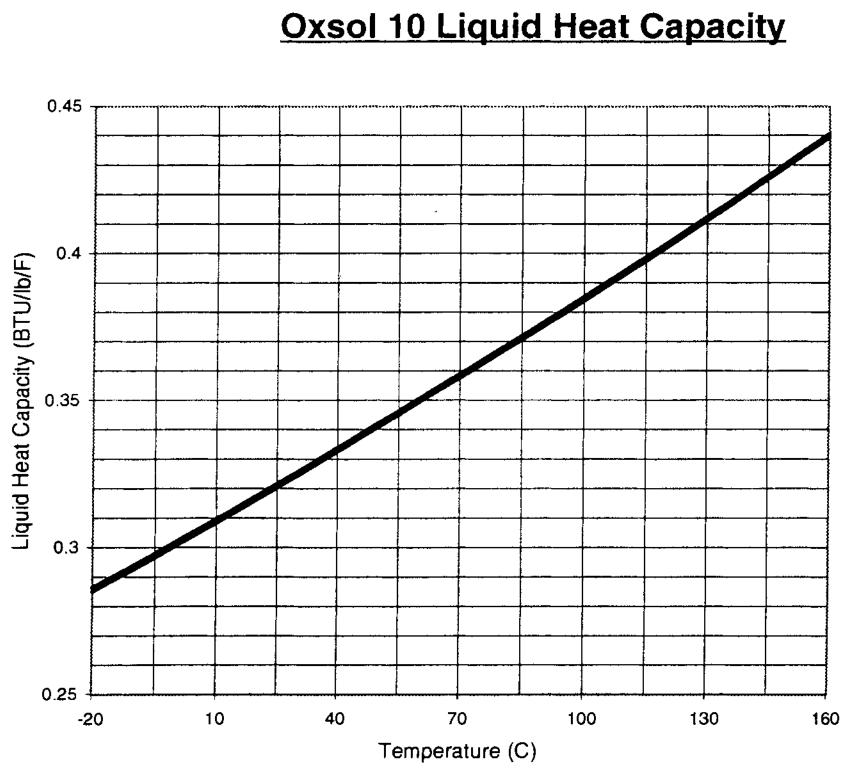
Formula	C_7H_7Cl
Molecular weight	126.59
Specific gravity @ 25°C/25°C	1.07
Density, lb/gal (g/l)	9 (1070)
Freeze point, °C (°F)	-25 (-13)
Boiling point, °C (°F)	159 (318)
Flash point (TCC), °C (°F)	50.6 (123)
Vapor pressure @ 20°C, mm Hg	2.6
Kauri-butanol value	110
Water, ppm	<100

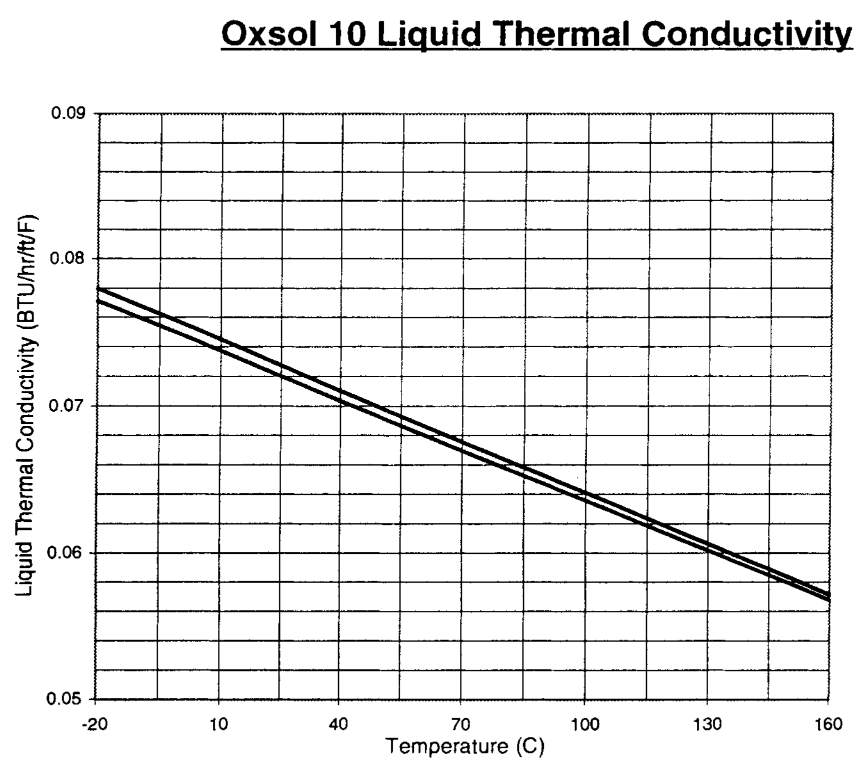
Oxsol 10 Liquid Density



(continued)

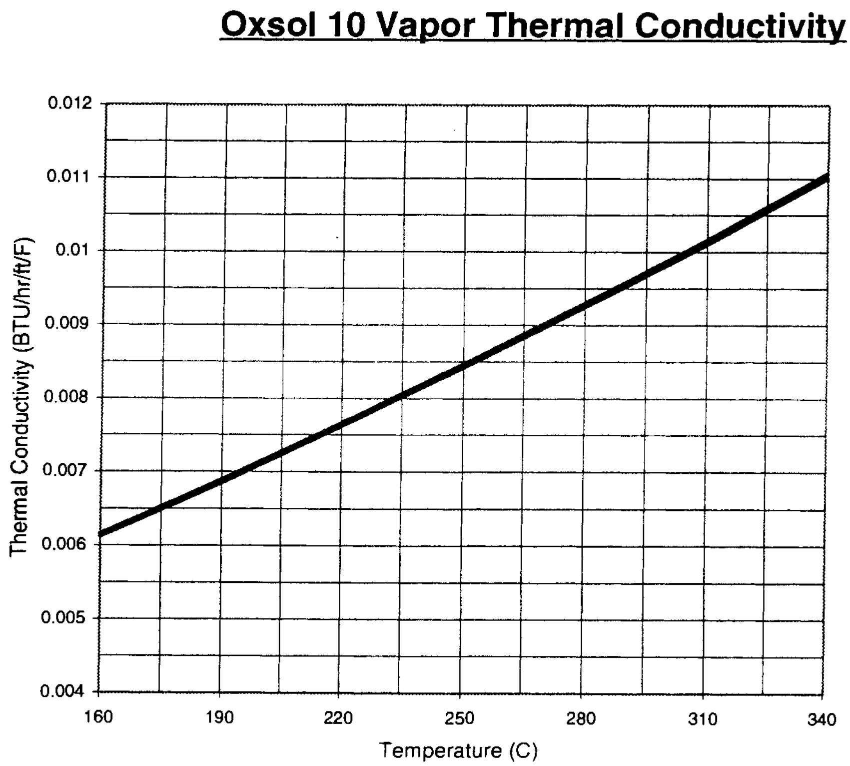
Table 3.63: (continued)

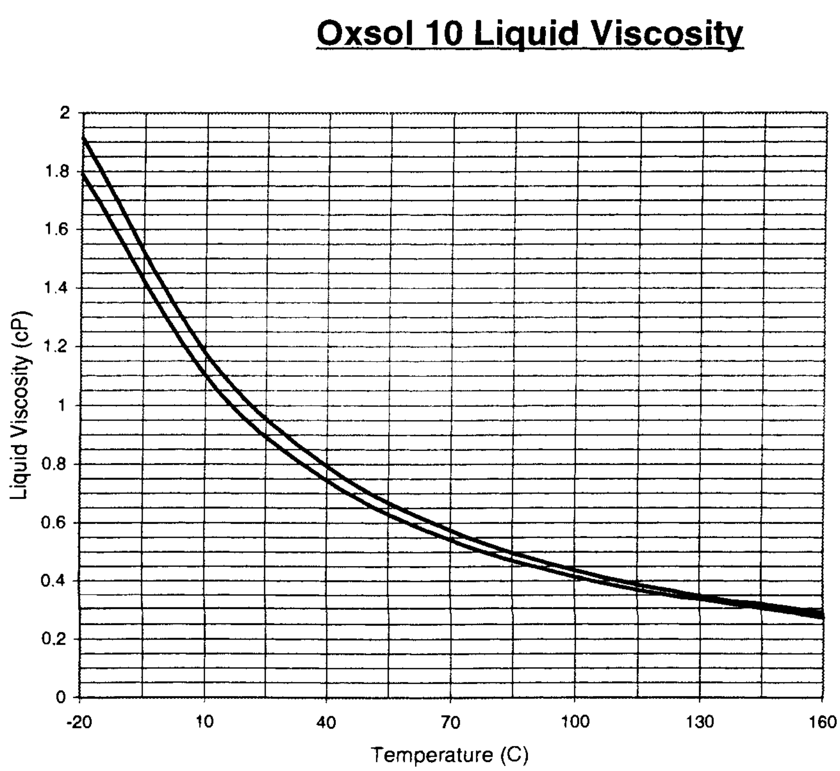




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Table 3.63: (continued)

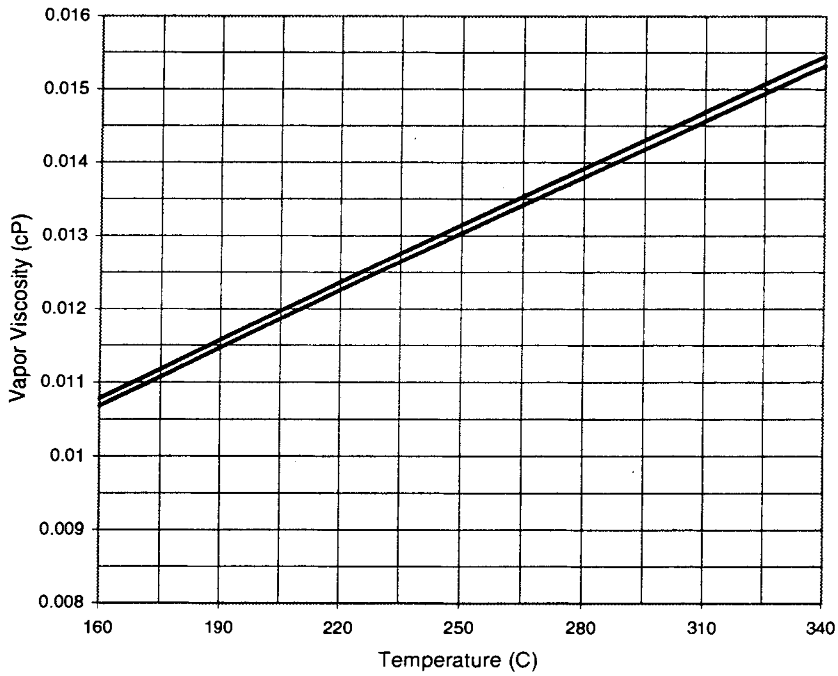




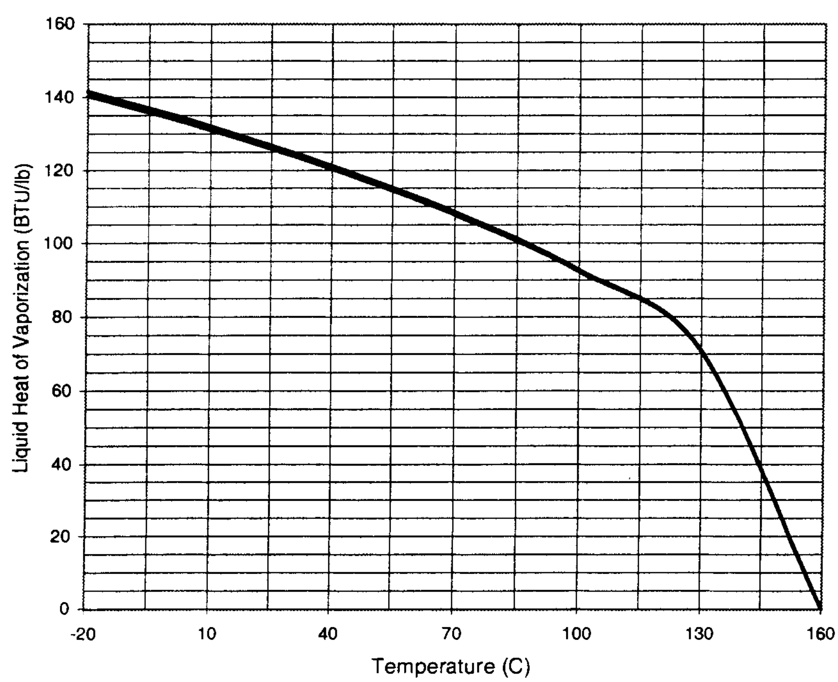
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Table 3.63: (continued)

Oxsol 10 Vapor Viscosity



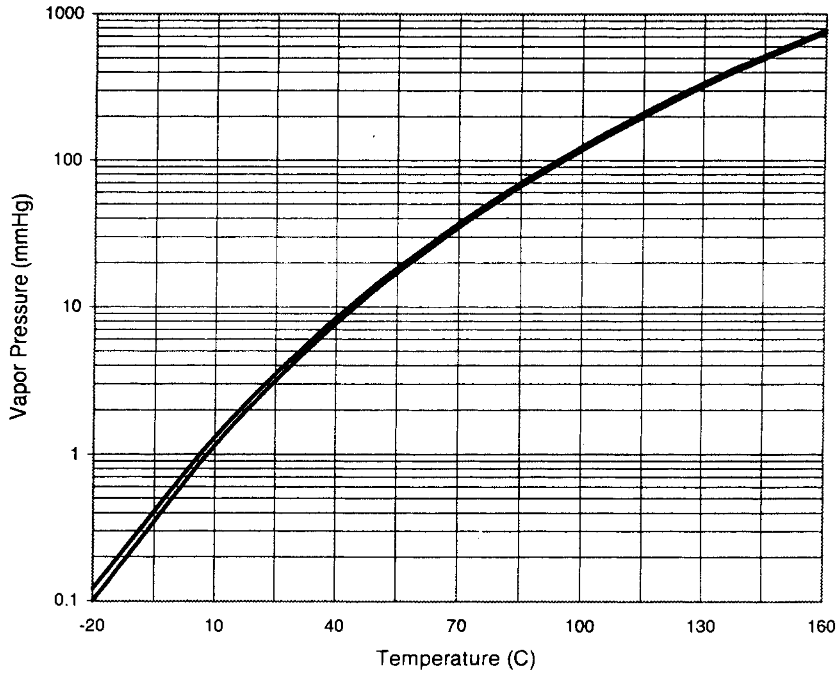
Oxsol 10 Liquid Heat of Vaporization



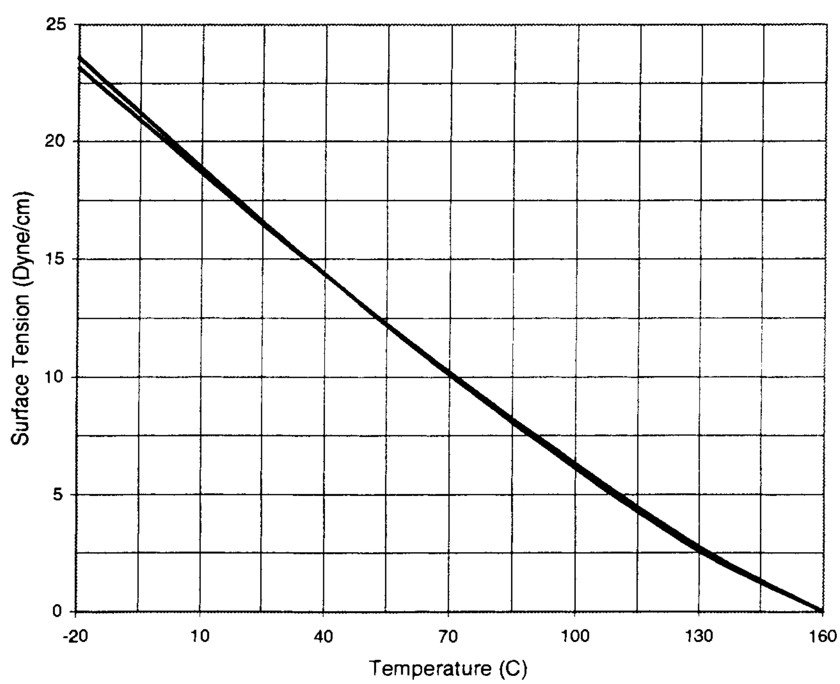
(continued)

Table 3.63: (continued)

Oxsol 10 Liquid Vapor Pressure



Oxsol 10 Liquid Surface Tension



(continued)

Table 3.63: (continued)

OXSOL 100

OXSOL 100 is a purified grade of p-chlorobenzotrifluoride (PCBTF) with the characteristic odor of chlorinated aromatic solvents. OXSOL 100 is a clear water-white liquid with solvency characteristics similar to the classical chlorinated and fluorinated solvents. PCBTF has been commercially produced for over thirty years as a chemical intermediate. OXSOL 100 has been used as a solvent since 1992 as a replacement for solvents with Ozone Depletion Potential (ODP), Volatile Organic Compounds (VOC) and Hazardous Air Pollutants (HAP).

OXSOL 100 is not regulated as an ozone depleter. OXSOL 100 is not regulated as a Hazardous Air Pollutant. And on October 5, 1994, the EPA published in the Federal Register, a revised definition of VOC which specifically exempted OXSOL 100 from VOC regulations. The exemption was based on the very favorable atmospheric profile of the molecule.

The use of OXSOL 100 or other PCBTF based OXSOLs will allow many solvent users to eliminate or reduce their use and emissions of VOCs without giving up the many benefits received from organic solvents. OXSOL can be used to extend or replace many organic solvents, including toluene, xylene, mineral spirits, acetone, methyl ethyl ketone (MEK), trichloroethylene, perchloroethylene, 1,1,1-trichloroethane and n-methyl pyrrolidone (NMP)>

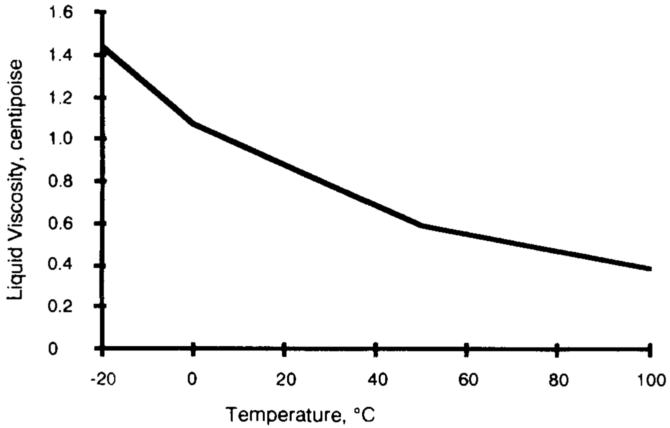
Physical Properties of OXSOL 100	
Freezing Point, °C	-36
Boiling Point, °C	139
Flash Point, TCC, °F	109
Evaporation Rate at 25°C, n-BuAc = 1	0.9
Solubility Parameter $(cal/cm^3)^{1/2}$	7.3
Density @ 25°C, lb/gal	11.2
Kauri-Butanol Value	64
Solubility of water in OXSOL @ 25°C, ppm	240
Solubility of OXSOL in water @ 25°C, ppm	35
Surface Tension @ 25°C, $dynes/cm^2$	25
Heat of Combustion, BTU/lb	7100
Viscosity @ 25°C, cp	0.79
CAS#	98-56-6

Sales Specifications	
Appearance	CFOSM
Color, APHA	20 Max
Acidity, ppm (by specific ion probe)	3 Max
Alkalinity, ppm as NaOH	10 Max
Water content, ppm	150 Max
Specific Gravity @ 25°C/25°C	1.33-1.35
Non Volatile Residue, Wt. %	0.0020 Max

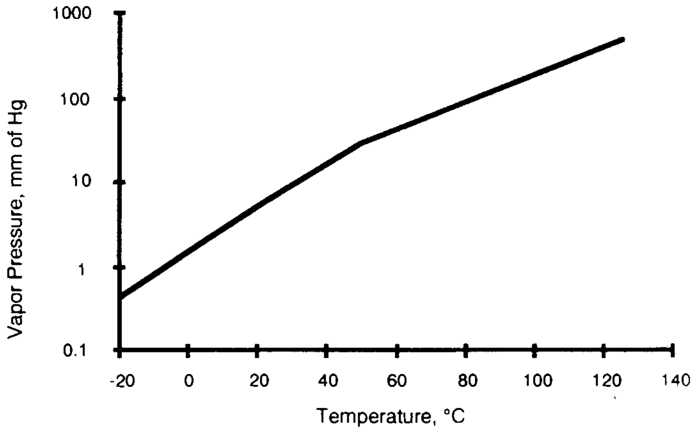
(continued)

Table 3.63: (continued)

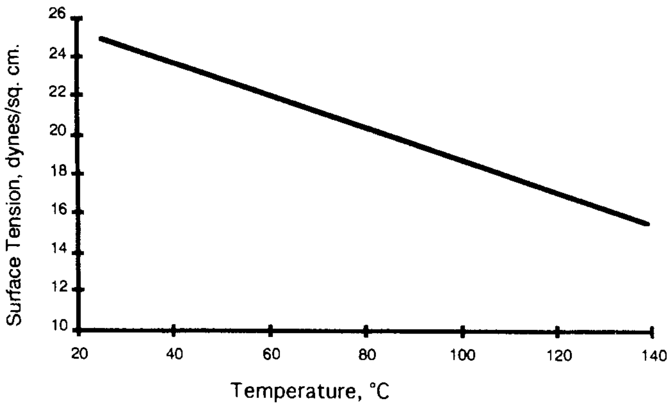
Liquid Viscosity



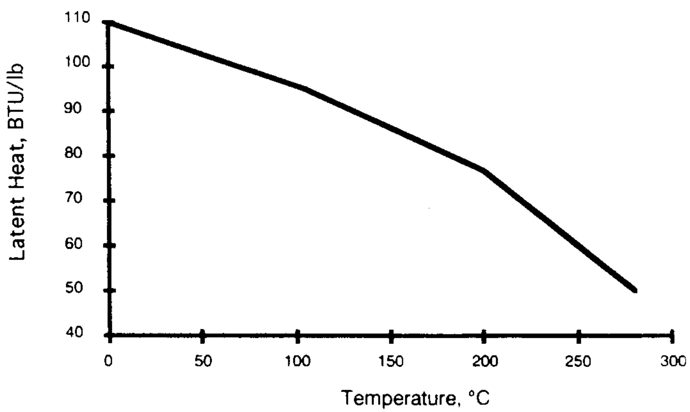
Vapor Pressure



Surface Tension



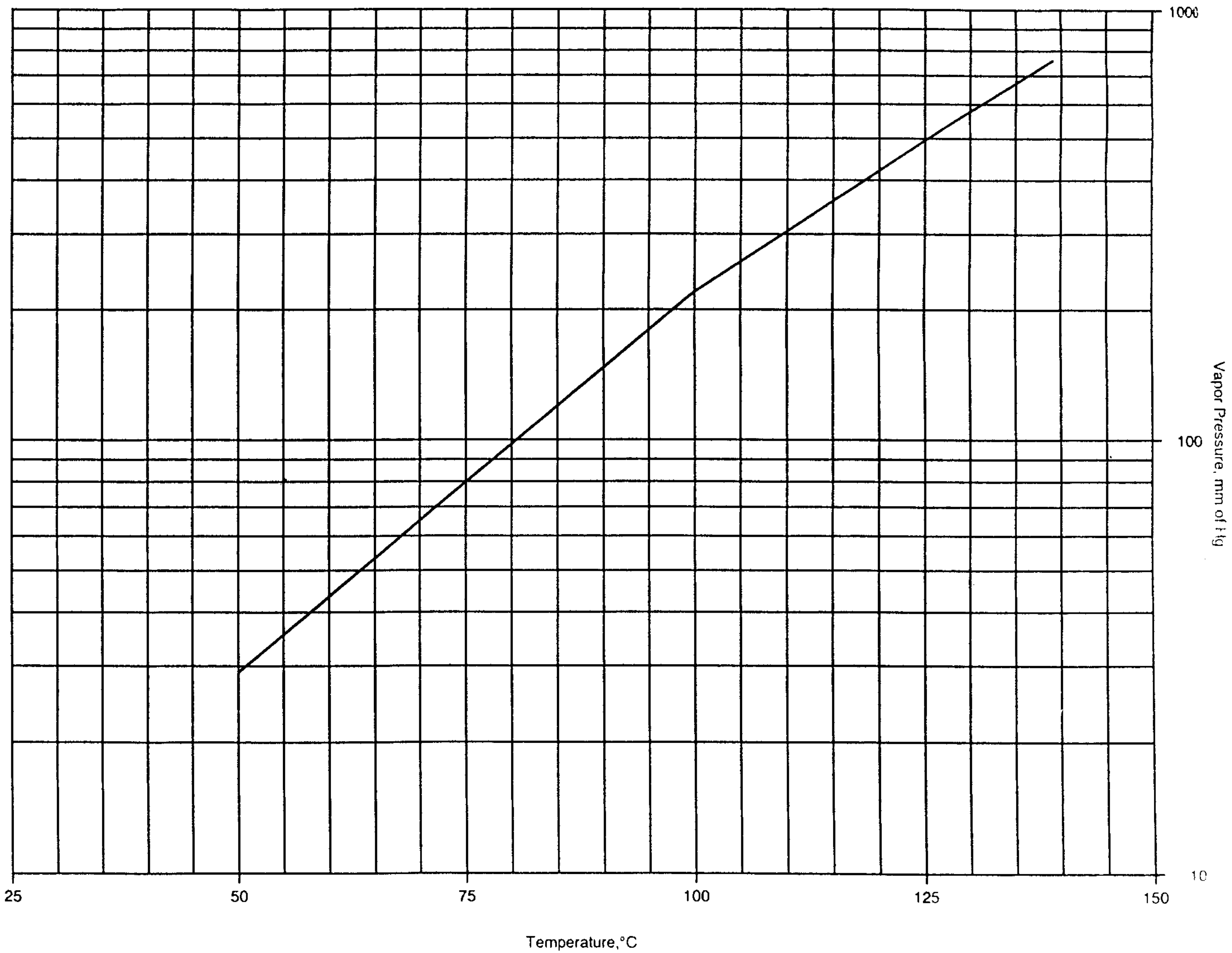
Latent Heat of Vaporization



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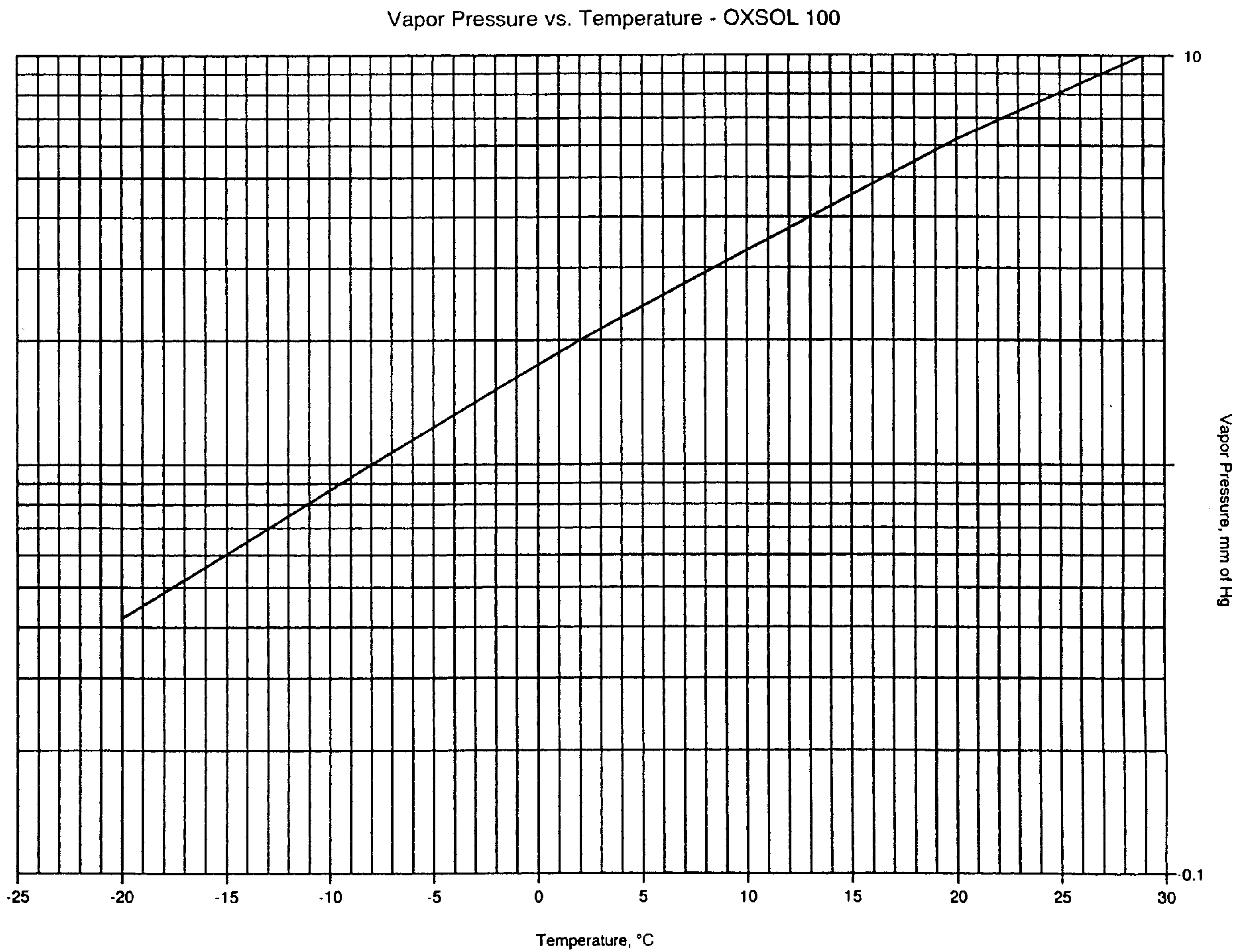
Table 3.63: (continued)

Vapor Pressure vs. Temperature - OXSOL 100



(continued)

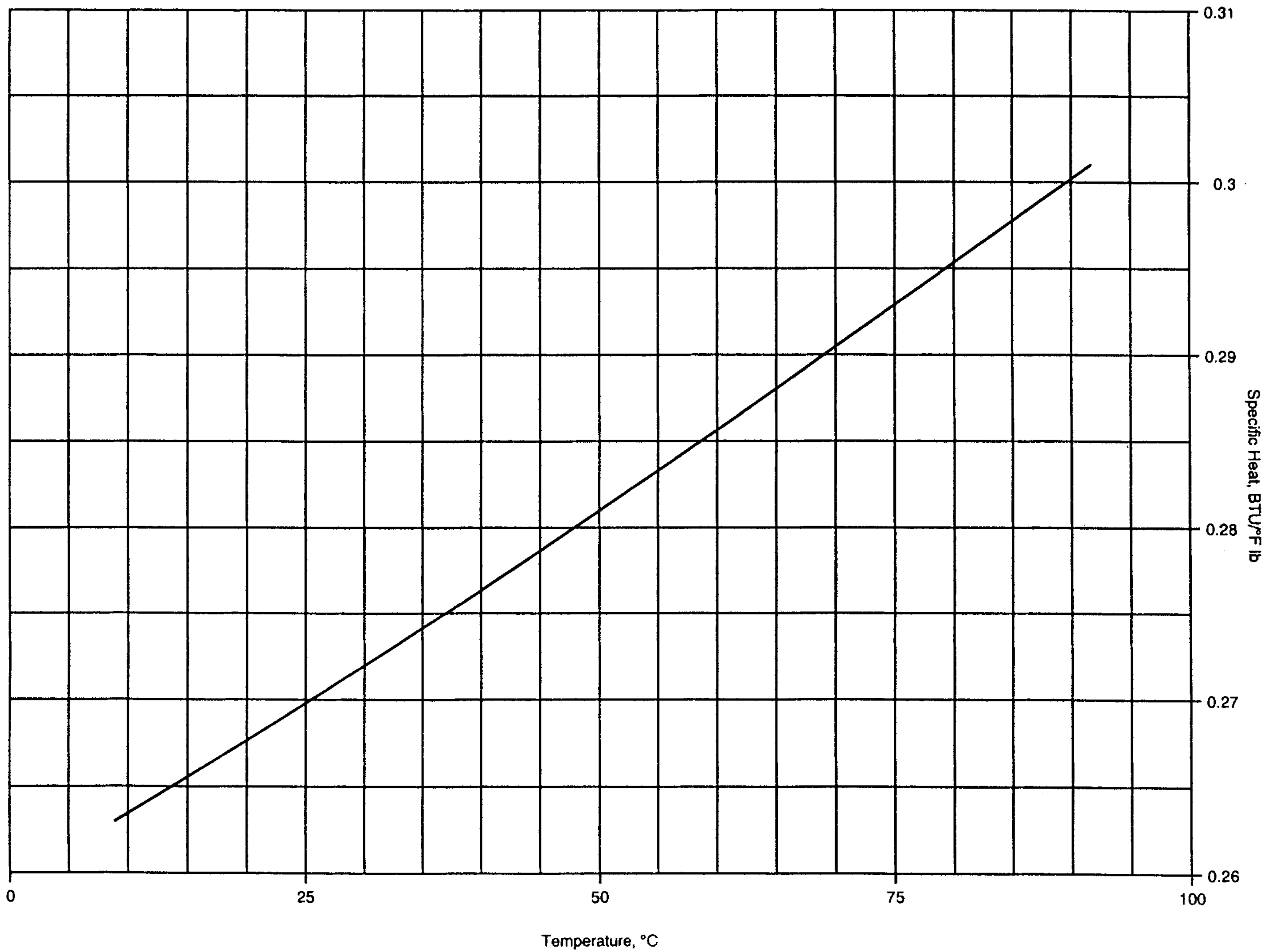
Table 3.63: (continued)



(continued)

Table 3.63: (continued)

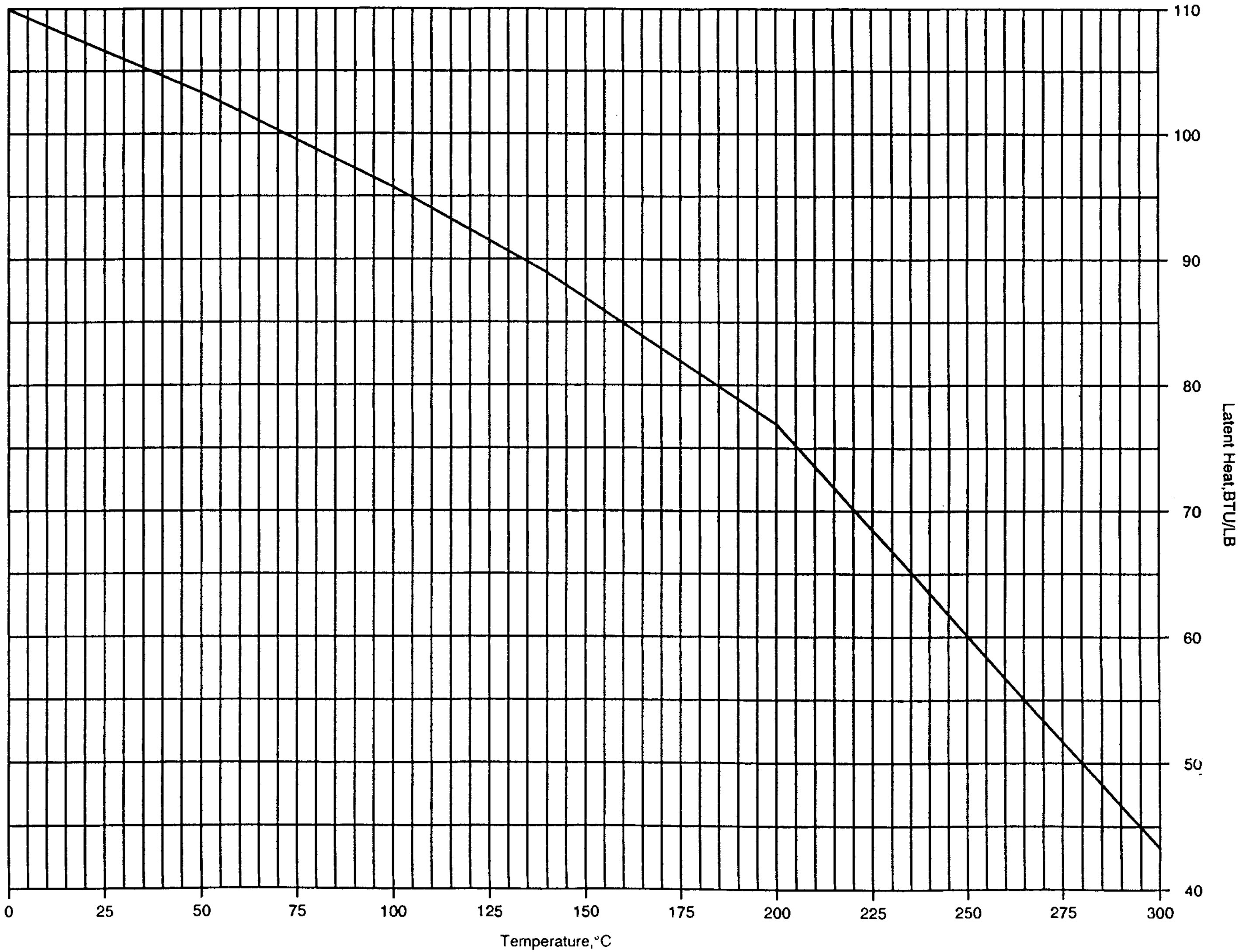
Specific Heat vs. Temperature - OXSOL 100



(continued)

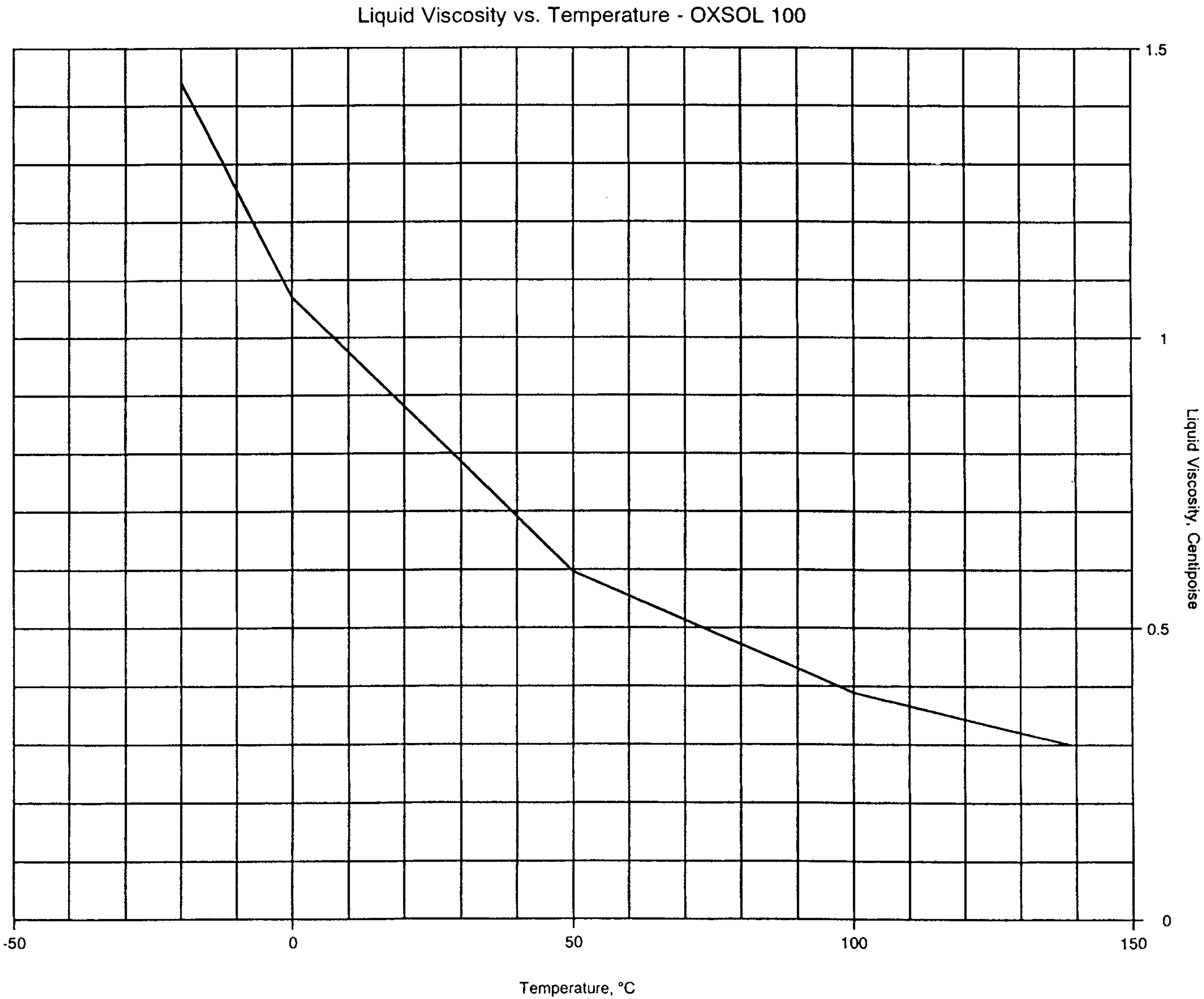
Table 3.63: (continued)

Latent Heat vs Temperature - OXSOL 100



(continued)

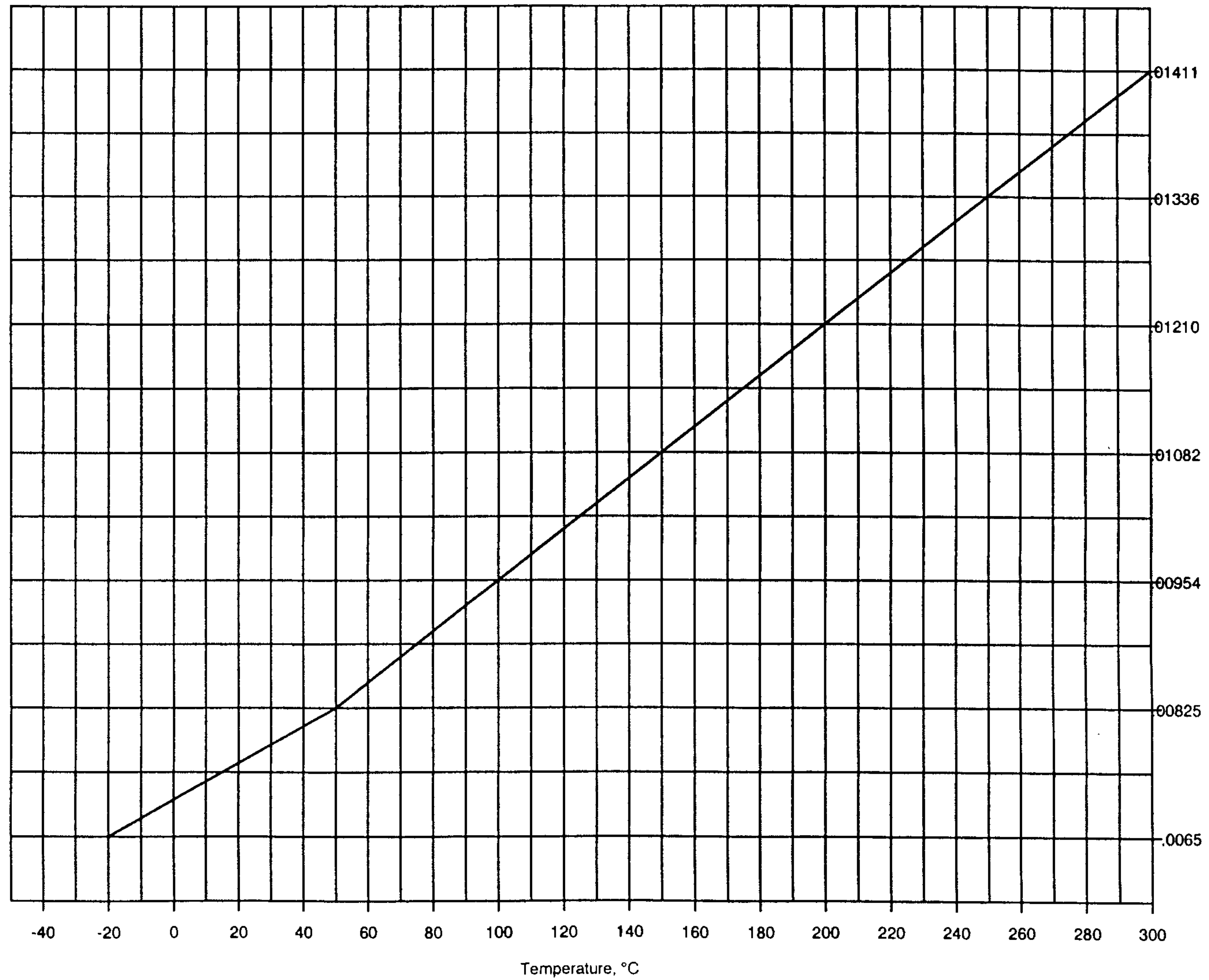
Table 3.63: (continued)



(continued)

Table 3.63: (continued)

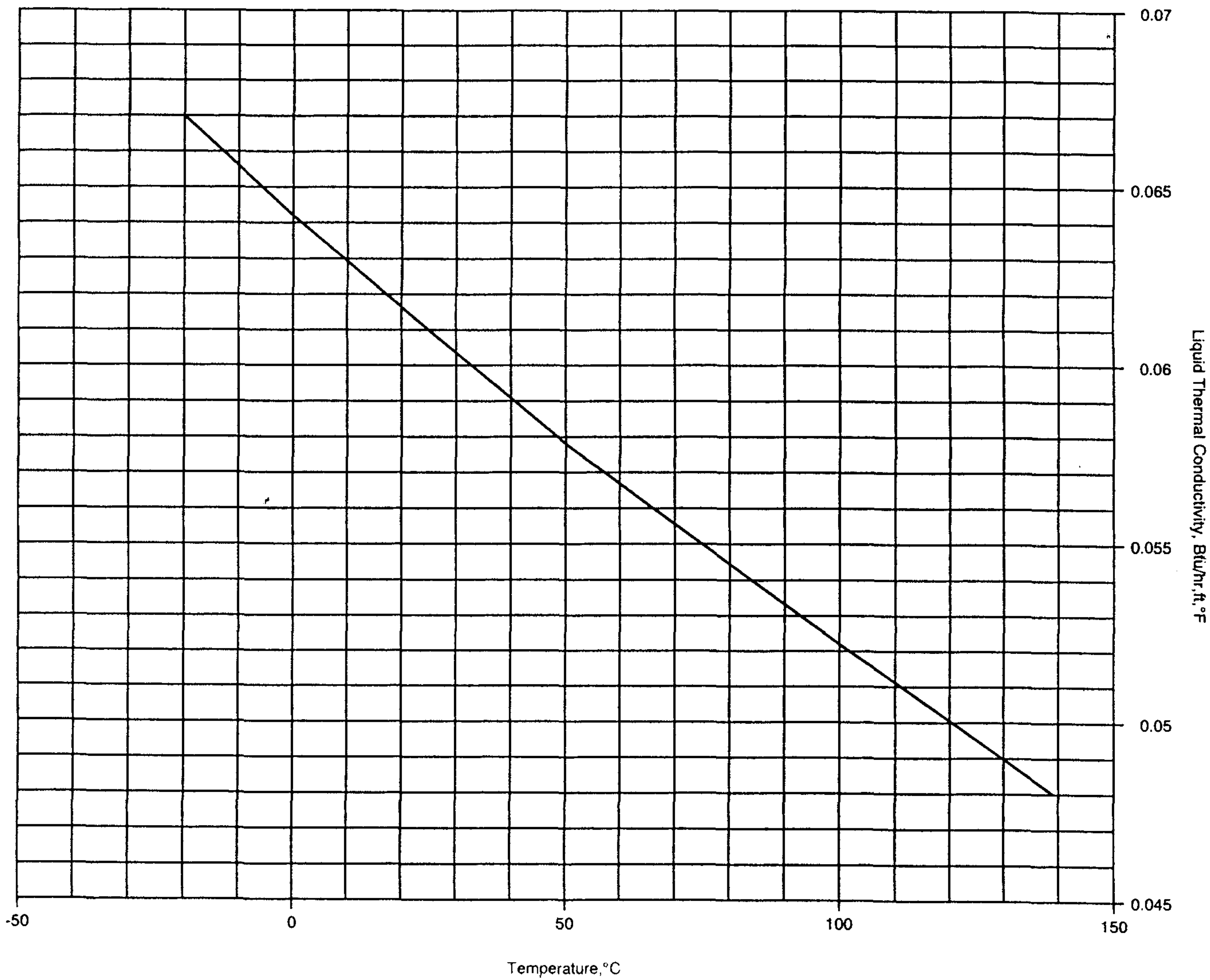
Vapor Viscosity vs. Temperature - OXSOL 100



(continued)

Table 3.63: (continued)

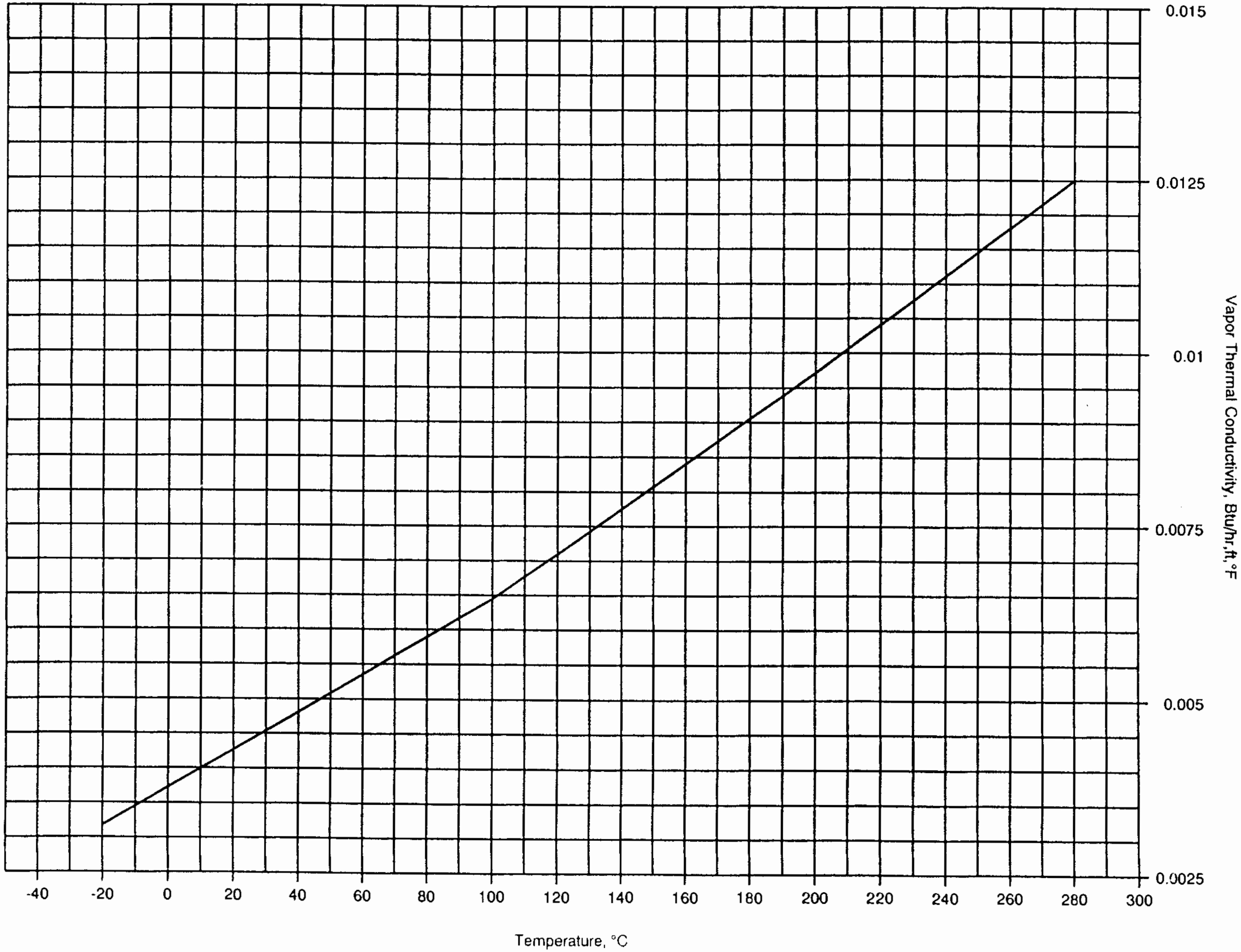
Liquid Thermal Conductivity vs. Temperature - OXSOL 100



(continued)

Table 3.63: (continued)

Vapor Thermal Conductivity vs. Temperature - OXSOL 100



(continued)

Table 3.63: (continued)

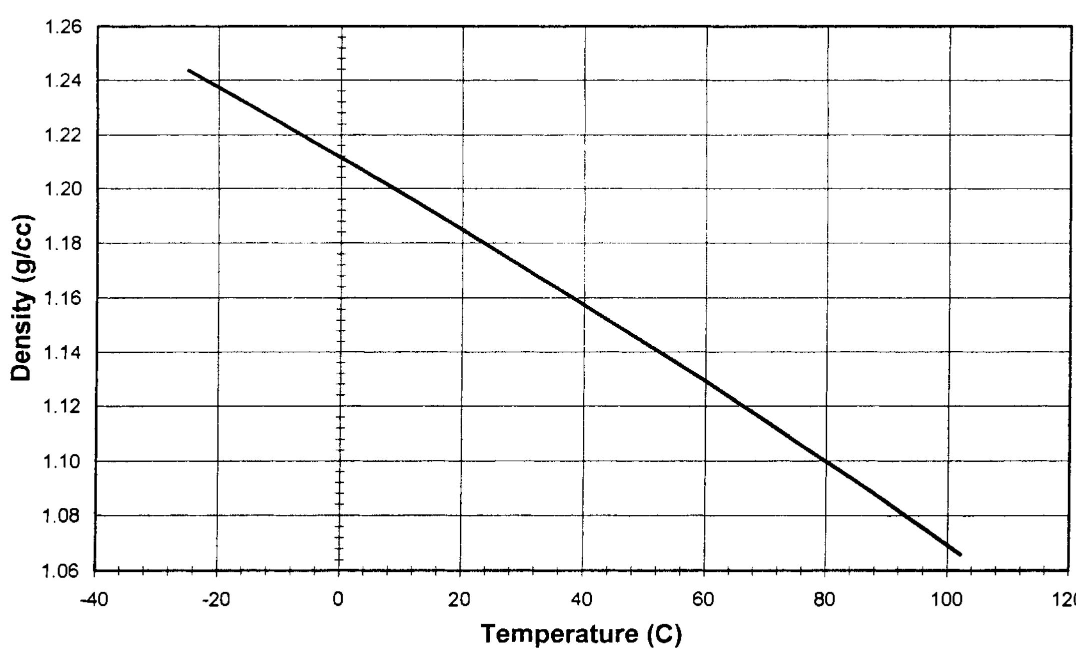
OXSOL 2000

Chemically, OXSOL 2000 is alpha, alpha, alpha-trifluorotoluene, an HFC. OXSOL 2000 has a number of desirable properties for precision cleaning, electronics cleaning, aerosol applications, and wipe cleaning. It is a pure compound, with a relatively fast evaporation rate and toluene-like odor. In its pure form, OXSOL 2000 is a good replacement for hexane, toluene, and VM&P naphtha where a rapid evaporation rate is desirable and a flammable solvent can be used safely. In addition, OXSOL 2000 can be blended with classical solvents like trichloroethylene yielding non-flammable, very fast evaporating compositions.

Physical and Chemical Properties of OXSOL 2000:

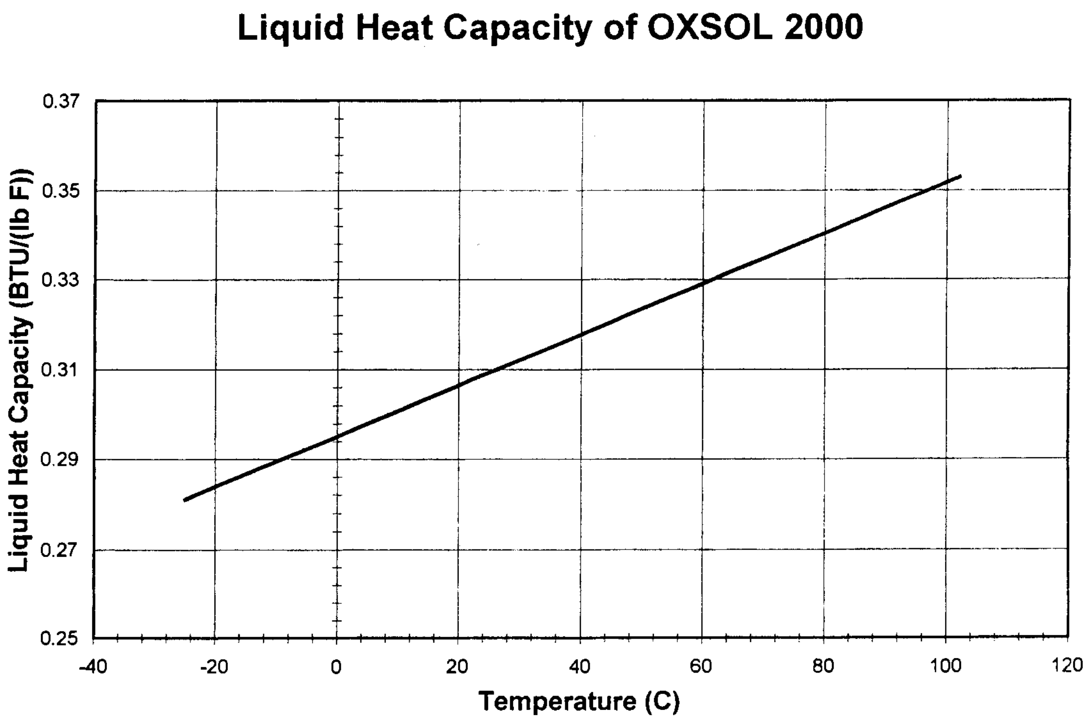
Property	
Chemical Formula	$C_7H_5F_3$
Molecular Weight	146.11
Boiling Point: °C (°F)	102 (216)
Dielectric Constant, 25°C	11.5
Flash Point, TCC °C (°F)	12 (54)
Fire Point, TOC °C (°F)	23 (74)
Kauri Butanol Value	49
Evaporation Rate, n-BuAc = 1	2.8
Latent Heat of Vaporization (B.P.), BTU/lb	97
Specific Heat, Liquid 20°C (BTU/lb/°F)	0.306
Density, 20°C, gm/cc	1.185
Density, 20°C, lbs/gal	9.88
Vapor Pressure (20°C), mm Hg	30
Vapor Density (Air = 1)	5.0
Surface Tension in Air: Dynes/cm:20°C	23
Viscosity (Cp), Liquid, 20°C	0.56

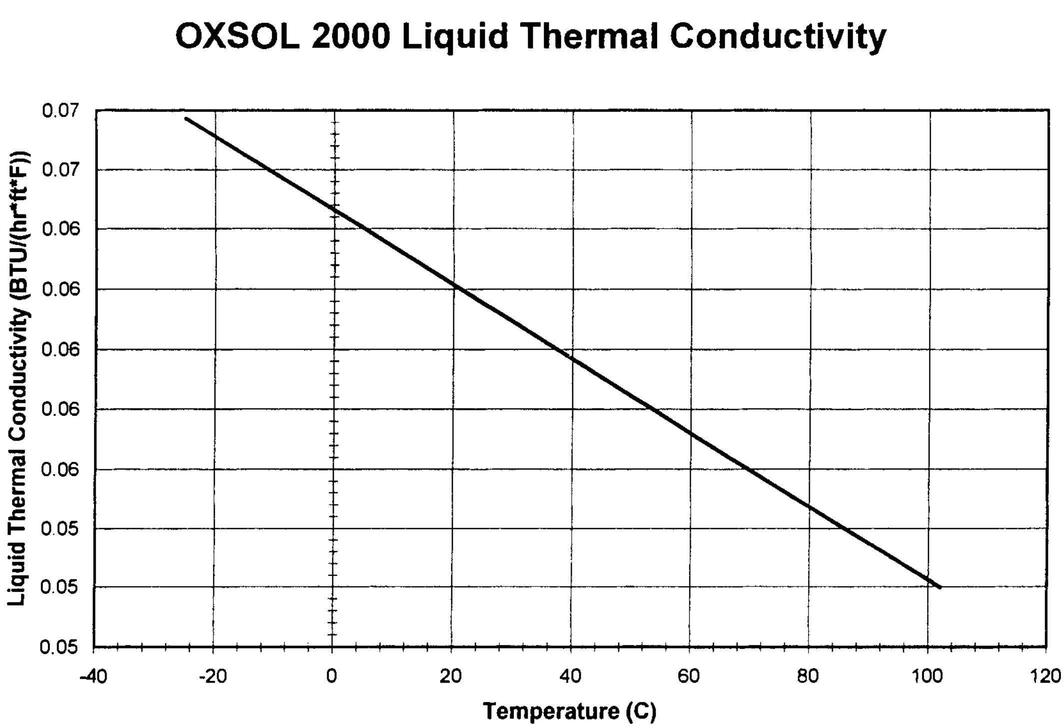
Density of OXSOL 2000



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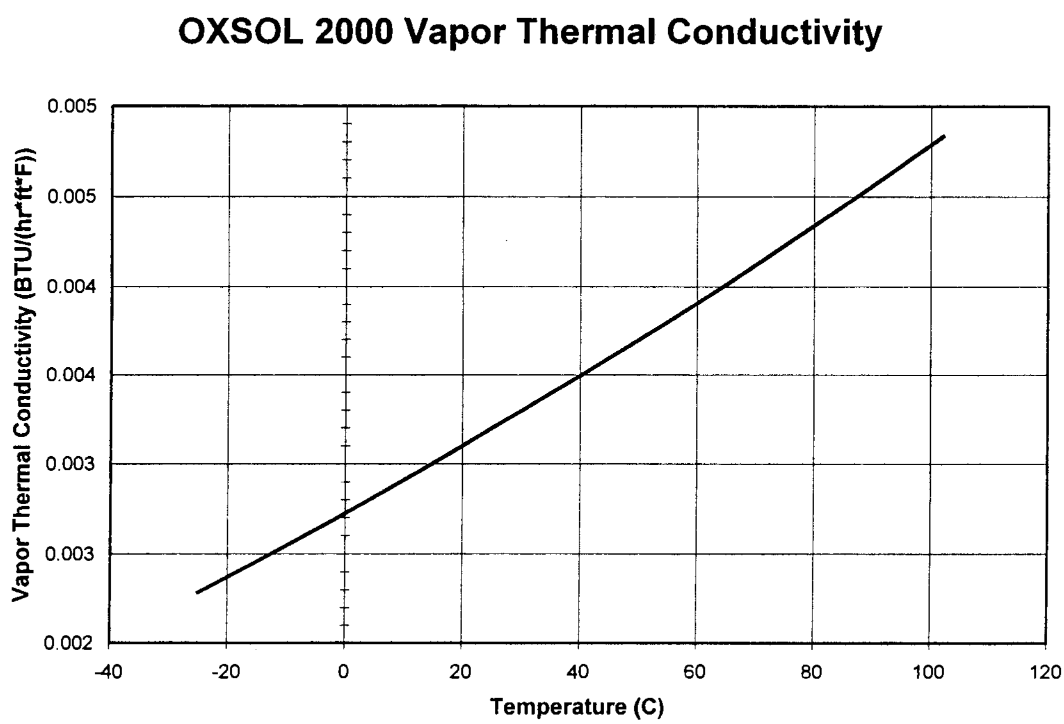
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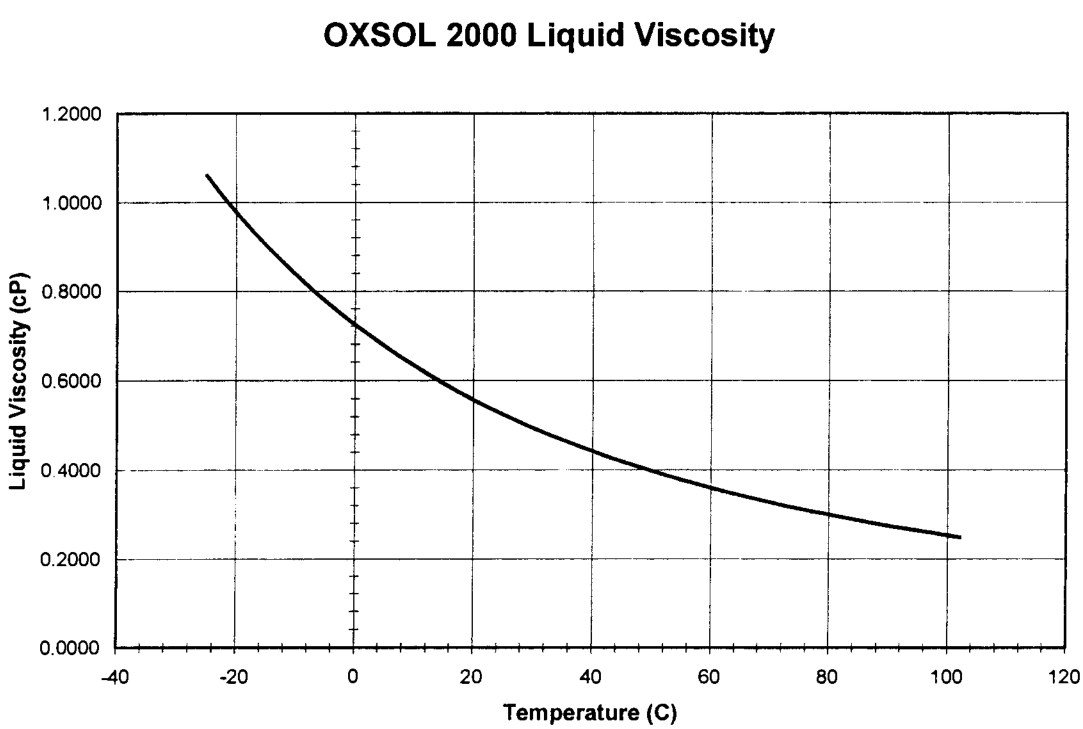




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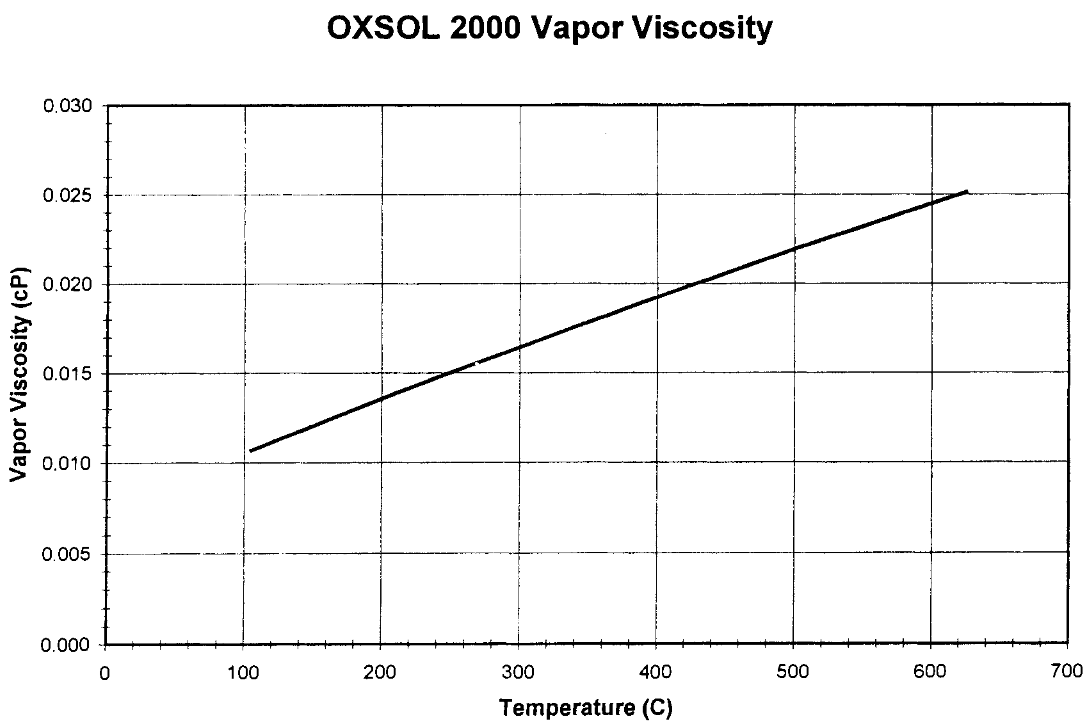
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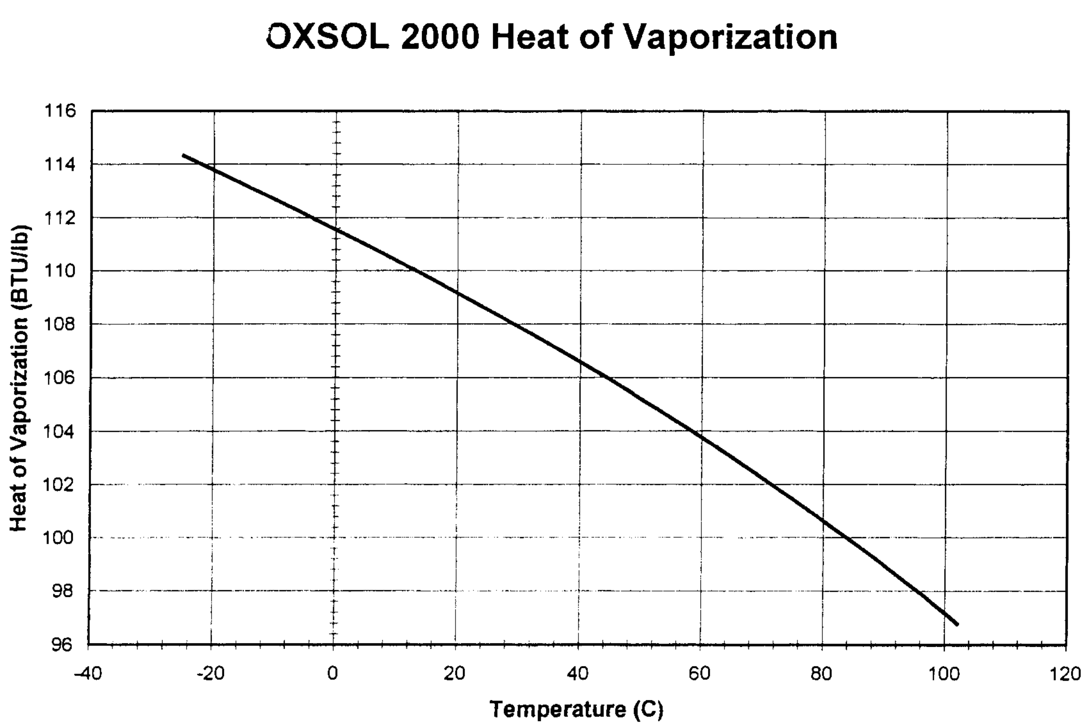




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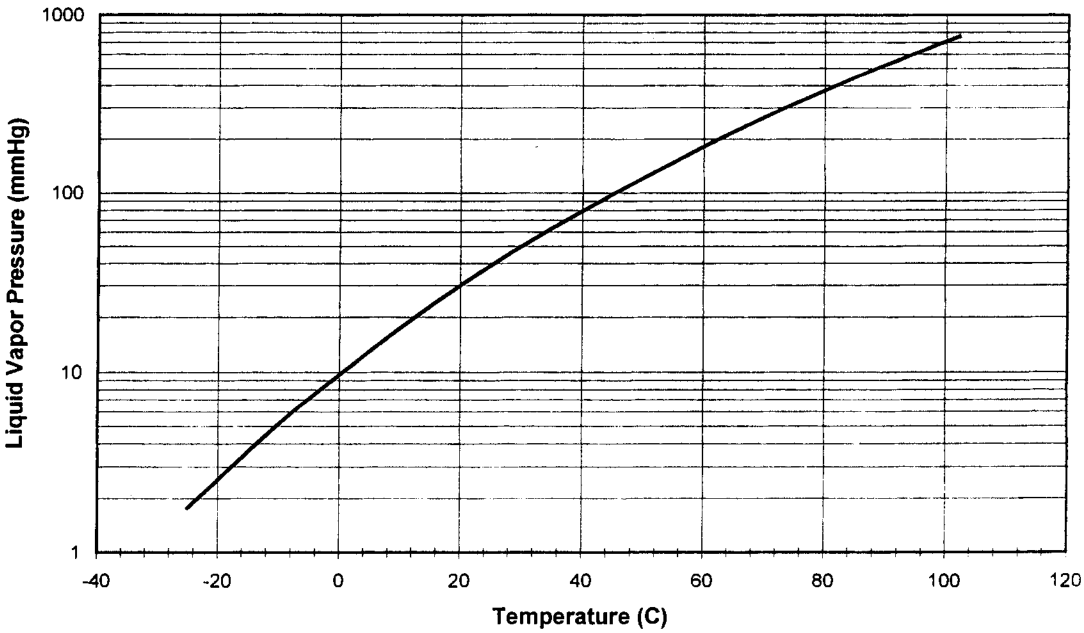




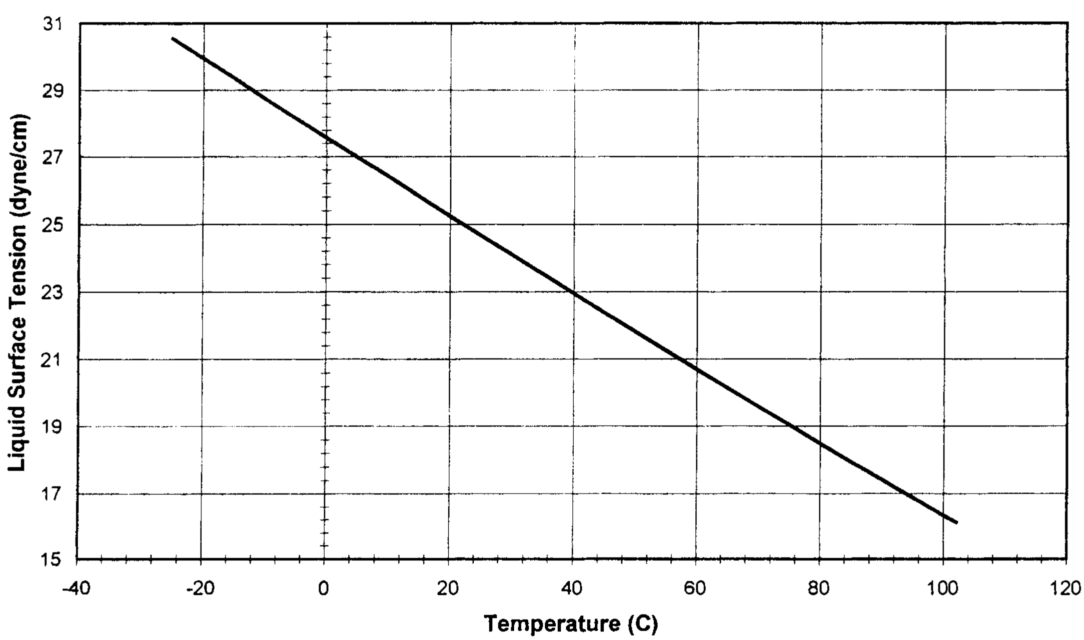
(continued)

Table 3.63: (continued)

OXSOL 2000 Liquid Vapor Pressure



OXSOL 2000 Liquid Surface Tension



(continued)

Table 3.63: (continued)

Sales Specification

OXSOL® 550

Test	Specifications
Appearance	Clear, Free of Suspended Matter
Color, APHA	30 Max.
Acidity, ppm as Total Inorganic Acidity (by Specific Ion Probe)	3 Max.
Alkalinity, ppm as NaOH	10 Max.
Water Content, ppm	150 Max.
Specific Gravity @ 25°C/25°C	1.20-1.22
Residue on Evaporation, Wt. %	0.0025 Max.

Physical Properties

OXSOL 550 is a clear, colorless blend of Halogenated Aromatic solvents with a characteristic chloroaromatic odor and the following physical characteristics:

Distillation Range, @ 760 mm Hg	142-159°C
Flash Point, (TCC)	113°F
Freezing Point	<-60°C
Evaporation Rate (n-BuAc=1.0)	0.7
Solubility, @ 25°C	<150 ppm in H_2O
Density, @ 25°C	10.11 lbs/gal
Vapor Pressure, @ 20°C	3.9 mm Hg
Heat of Combustion	9,900 BTU/lb
Kauri-Butanol Value	92

Sales Specification

OXSOL® 73

Test	Specifications
Appearance	Clear, Free of Suspended Matter
Color, APHA	30 Max.
Acidity, ppm as Total Inorganic Acidity (by Specific Ion Probe)	3 Max.
Alkalinity, ppm as NaOH	15 Max.
Water Content, ppm	100 Max.
Specific Gravity @ 25°C/25°C	1.22-1.26
Residue on Evaporation, Wt. %	0.0025 Max.

Physical Properties

OXSOL 73 is a clear, colorless, non-flammable blend of Monochlorotoluenes and Perchloroethylene with a characteristic chloroaromatic odor and the following physical characteristics:

Distillation Range, @ 760 mm Hg	129-158°C
Flash Point, (TCC)	NFTB *
Freezing Point	-33°C
Evaporation Rate (n-BuAc=1.0)	0.6
Solubility, @ 25°C	<150 ppm in H_2O
Density, @ 25°C	10.35 lbs/gal
Vapor Pressure, @ 20°C	8-10 mm Hg
Heat of Combustion	8,300 BTU/lb
Kauri-Butanol Value	114

* NFTB - No Flash to Boiling

(continued)

Table 3.63: (continued)

Sales Specification

OXSOL® 253

Test	Specifications
Appearance	Clear, Free of Suspended Matter
Color, APHA	30 Max.
Acidity, ppm as Total Inorganic Acidity (by Specific Ion Probe)	3 Max.
Alkalinity, ppm as NaOH	15 Max.
Water Content, ppm	100 Max.
Specific Gravity @ 25°C/25°C	1.27-1.32
Residue on Evaporation, Wt. %	0.0025 Max.

Physical Properties

OXSOL 253 is a clear, colorless, non-flammable blend of Halogenated Aromatics and Perchloroethylene with a characteristic chloroaromatic odor and the following physical characteristics:

Distillation Range, @ 760 mm Hg	127-159°C
Flash Point, (TCC)	NFTB *
Freezing Point	<-60°C
Evaporation Rate (n-BuAc=1.0)	0.6
Solubility, @ 25°C	<150 ppm in H_2O
Density, @ 25°C	10.81 lbs/gal
Vapor Pressure, @ 20°C	10 mm Hg
Heat of Combustion	7,600 BTU/lb
Kauri-Butanol Value	109

* NFTB - No Flash to Boiling

Sales Specification

OXSOL® 325

Test	Specifications
Appearance	Clear, Free of Suspended Matter
Color, APHA	30 Max.
Acidity, ppm as Total Inorganic Acidity (by Specific Ion Probe)	3 Max.
Alkalinity, ppm as NaOH	15 Max.
Water Content, ppm	100 Max.
Specific Gravity @ 25°C/25°C	1.40-1.46
Residue on Evaporation, Wt. %	0.0025 Max.

Physical Properties

OXSOL 325 is a clear, colorless, non-flammable blend of Halogenated Aromatics and Perchloroethylene with a characteristic chloroaromatic odor and the following physical characteristics:

Distillation Range, @ 760 mm Hg	121-155°C
Flash Point, (TCC)	NFTB *
Freezing Point	<-50°C
Evaporation Rate (n-BuAc=1.0)	1.2
Solubility, @ 25°C	<150 ppm in H_2O
Density, @ 25°C	11.95 lbs/gal
Vapor Pressure, @ 20°C	13 mm Hg
Heat of Combustion	5,100 BTU/lb
Kauri-Butanol Value	100

* NFTB - No Flash to Boiling

(continued)

Table 3.63: (continued)

OXSOL SA

OXSOL SAs are based on parachlorobenzotrifluoride (PCBTF or OXSOL 100), an "environmentally friendly" solvent alternative. PCBTF has a unique atmospheric profile, making it one of the few volatile organic solvents not suspected of causing stratospheric ozone depletion or tropospheric ozone and smog. PCBTF is not an ozone depleting product (ODP). It is exempt from USEPA Volatile Organic Compounds (VOC) regulations. It is not a hazardous air pollutant (HAP). It is not on the SARA Title III, Section 313 list of toxic chemicals. It is not a carcinogen and is considered only "mildly toxic" (from Federal Register 50 FR 42216-4221 10/18/85.

As a result of its favorable regulatory status and excellent properties, PCBTF is an ideal candidate for formulating environmentally friendly solutions without giving up the excellent physical and chemical properties of organic solvents.

OXSOL®
Dielectric Breakdown*

Product	Test #1 (kv)	Test #2 (kv)
OXSOL 73	30	38
OXSOL 253	50+	50+
OXSOL 325	50+	50+
OXSOL 550	35	40
OXSOL 100	48	50
OXSOL 1000	40	50

* ASTM Test Method D-877; Reported in thousands of volts.

Sales Specification

OXSOL® 1000

Test	Specifications
Appearance	Clear, Free of Suspended Matter
Color, APHA	20 Max.
Acidity, ppm as Total Inorganic Acidity (by Specific Ion Probe)	3 Max.
Alkalinity, ppm as NaOH	10 Max.
Water Content, ppm	150 Max.
Specific Gravity @ 25°C/25°C	1.47-1.49
Residue on Evaporation, Wt. %	0.0020 Max.

Physical Properties

OXSOL 1000 (3,4-Dichlorobenzotrifluoride) is a clear, colorless solvent with the following physical characteristics:

Boiling Point, @ 760 mm Hg	174°C
Flash Point, (TCC)	170°F
Freezing Point	-12.4°C
Evaporation Rate (n-BuAc=1.0)	0.2
Solubility, @ 25°C	11.6 ppm in H_2O
Density, @ 25°C	12.36 lbs/gal
Vapor Pressure, @ 20°C	1.6 mm Hg
Heat of Combustion	4,830 BTU/lb
Kauri-Butanol Value	69

Table 3.64: 3M Hydrofluoroether

3M™ HFE-7100, methoxy-nonafluorobutane ($C_4F_9OCH_3$), is a clear, colorless and low-odor fluid intended to replace ozone-depleting materials. This proprietary fluid has zero ozone depletion potential and other favorable environmental properties. It has one of the lowest toxicological profiles of the new CFC replace materials, with a time-weighted average exposure guideline of 600 ppm (eight hour average).

The high boiling point, increased solvency and low surface tension of 3M HFE-7100 make it suitable for use in vapor degreasing applications as a neat (pure), azeotropic or co-solvent parts cleaner. In addition, its chemical and thermal stability, non-flammability and low toxicity make it useful for other industrial applications such as specialty solvent and heat transfer applications.

Typical 3M HFE-7100 Applications

- Cleaning and Rinsing Agent
  - Heavy-duty (co-solvent) cleaning - heavy oils, greases, fluxes
  - Medium-duty cleaning (azeotrope) - oils, greases, waxes
  - Light-duty cleaning (neat) - particulates, fluorolubes, light oils, fluoropolymers
- Lubricant Carrier
  - Fluorocarbons
  - Hydrocarbons
  - Silicones
- Spot-Free Water Drying Agent
  - (with surfactants added)
- Specialty Solvents, Dispersion Medium
- Heat Transfer Medium
- Spray Contact Cleaner
- CFC, HCFC, HFC and PFC Replacement Agent

Heat Transfer Properties

Properties	3M HFE-7100	CFC-113	HCFC-141b	HCFC-225 ca/cb	HFC-4310
Vapor Pressure[1]	210	331	569	290	226
Viscosity[2]	0.61	0.68	0.43	0.59	0.67
Heat of Vaporization[3]	30	35	53.3	34.6	31
Specific Heat[4]	0.28	0.22	0.30	0.24	0.27

[1] mmHg @ 25°C
[2] cps @ 25°C
[3] cal/g @ boiling point
[4] cal/g °C @ 25°C

Data compiled from published information.

Environmental Properties

Property	3M HFE-7100	CFC-113	HCFC-141b	HCFC-225 ca/cb	HFC-4310
Ozone Depletion Potential[1]-ODP	0.00	0.80	0.10	0.03	0.00
Global Warming Potential[2]-GWP	500	5000	630	170/530	1300
Atmospheric Lifetime-ALT (yrs)	4.1	85	9.4	2.5/6.6	17.1

[1] CFC-11 = 1.0
[2] GWP - 100 year Integration Time Horizon (ITH)

NOTE: HCFC-225 ca/cb ratio is 45/55
Data compiled from published information

(continued)

Table 3.64: (continued)

Comparison Guide

Property	$C_4F_9OCH_3$ HFE-7100	$C_2Cl_3F_3$* CFC-113	CCl_2FCH_3* HCFC-141b	CH_3CCl_3* 1,1,1 TCA	$C_3Cl_2HF_5$* HCFC-225 ca/cb	$C_5H_2F_{10}$* HFC-4310
Boiling Point (°C)	60	48	32	74	54	54
Surface Tension (dynes/cm @ 25°C)	13.6	17.3	19.3	25.1	16.2	14.1
Heat of Vaporization (Cal/g) @ Boiling Point	30	35	53.3	58	35	31
Viscosity (cps @ 25°C)	0.61	0.68	0.43	0.77	0.59	0.67
Vapor Pressure (mmHg @ 25°C)	210	331	569	128	137-175	226
Specific Heat (Cal/g/°C @ 25°C)	0.28	0.22	0.30	0.25	0.24	0.27
Flash Point (°C)	NONE	NONE	NONE	NONE	NONE	NONE
Liquid Density (g/ml) @ 25°C	1.52	1.56	1.23	1.30	1.55	1.58
Freezing Point (°C)	-135	-35	-103	-39	-131	-80
Solubility for H_2O (ppm by wt.)	95	110	420	266	370	490
Solubility in H_2O (ppm by wt.)	<20	170	210	700	210	140
ODP (CFC-11 = 1.0)	0	0.8	0.10	0.1	0.03	0
Atmospheric Lifetime (Years)	4.1	85	9.4	5.4	2.5-6.6	17.1
GWP (100 Year ITH)	480	5000	630	110	170/530	1300
Toxicity Data						
Acute Inhalation (ppm) (4 hr. LC_{50}) 8 hr. Exposure Guideline (ppm)	>100M 600	ca50M 1000	62M 500	16M 350	37M 50	10M 200

Table 3.64: (continued)

3M HFE-7100 Toxicological Test Results

Acute Lethal Inhalation Concentration	>100,000 ppm (4 hr)
Oral	Practically non-toxic (>5g/kg)
Eye Irritation	Practically non-irritating
Skin Irritation	Minimally irritating
Skin Sensitization	Not a Skin Sensitizer
Inhalation Range Finding (28 day)	600 ppm Exposure Guideline[1]
Developmental Toxicity	No abnormal effects observed
Mutagenicity	Not a mutagen
Cardiac Sensitization	No signs of sensitization at exposures up to 100,000 ppm
Ecotoxicity	In Progress
90 Day Inhalation	In Progress

[1] Exposure Guideline set by the 3M Medical Department

3M HFE-7100 Materials Compatibility

Metals	Plastics	Elastomers
Aluminum	Acrylic	Butyl Rubber*
Copper	Polyethylene	Natural Rubber
Carbon Steel	Polypropylene	Nitrile Rubber
302 Stainless Steel	Polycarbonate	EPDM
Brass	Polyester	
Molybdenum	Epoxy	
Tantalum	PMMA	
Tungsten	PET	
Cu/Be Alloy C172	ABS	
Mg Alloy AZ32B		

Compatible after one hour exposure at boiling temperature.
**Butyl Rubber best for extended exposure >1 month.*
Exceptions: *some swelling of PTFE and Silicone Rubber.*
Some surface oxidation of copper during heat aging.

3M HFE-71DE Hydrofluoroether Azeotrope

3M™ HFE-71DE is a hydrofluoroether, Methyl Nonafluorobutyl Ethers ($C_4F_9OCH_3$), in an azeotrope formulation with trans-1,2-dichloroethylene. This mixture is a true azeotrope, with constant vapor and liquid composition at its boiling point. This fluid is suited to medium duty cleaning and degreasing tasks, as well as specialty solvent applications, and is intended to replace ozone-depleting materials. It has zero ozone depletion potential and other favorable environmental properties. 3M HFE-71DE has a time-weighted average exposure guideline of 600 ppm for the 3M™ HFE-7100 component, and 200 ppm for trans-1,2-dichloroethylene (8 hr average).

The increased solvency and low surface tension, nonflammability and constant composition during boiling of 3M HFE-71DE make it suitable for immersion and vapor degreasing applications. These properties also may make the azeotrope suitable for certain coating and lubricant deposition applications where increased solvency is required.

3M HFE-71DE Typical Applications

Cleaning, Rinsing and Drying Agent
  Cleaning of oils, greases, waxes
Specialty solvent applications
For information on other applications, contact your 3M representative or 3M authorized distributor.

(continued)

Table 3.64: (continued)

General Properties

Properties	3M HFE-71DE	CFC-113	HCFC-141b	HCFC-225 ca/cb	HFC-4310
Formulation	Azeotrope[1]	$C_2Cl_3F_3$	CCl_2FCH_3	$C_3Cl_2HF_5$	Azeotrope[2]
Boiling Pt °C	41	48	32	54	39
Freeze Pt °C	-24[3]	-35	-103	-131	not avail.
Liquid Density[4]	1.37	1.56	1.23	1.55	1.41
Surface Tension[5]	16.6	17.3	19.3	16.2	15.2
Kauri-Butanol Value	27	31	56	31	N/A
Flash Point	None	None	None	None	None
Flammability Range in Air	None	None	7.1-18.6[6]	None	N/A

[1] 50% 3M HFE-7100 ($C_4F_9OCH_3$), 50% trans-1, 2-dichloroethylene
[2] 61.7% HFC-4310 ($C_5H_2F_{10}$), 38% trans-1, 2-dichloroethylene (Dupont Vertrel MCA)
[3] Critical Solution Temperature
[4] g/mil @ 25°C
[5] dynes/cm @ 25°C
[6] Vol % by ASTM E681-94 @ 100°C

Physical Properties

Properties	3M™ HFE-71DE	CFC-113	HCFC-141b	HCFC-225 ca/cb	HFC-4310[1]
Vapor Pressure[2]	473	331	569	290	464
Viscosity[3]	0.45	0.68	0.43	0.59	0.49
Heat of Vaporization[4]	48	35	53.3	34.6	43.3
Ozone Depletion Potential-ODP[5]	0.00	0.80	0.10	0.03	0.00
Global Warming Potential[6]	250	5000	630	170/530	N/A
Atmospheric Lifetime (yrs)	4.1[7]	85	9.4	2.5/6.6	N/A

[1] 61.7% HFC-4310 ($C_5H_2F_{10}$), 38% trans-1, 2-dichloroethylene (Dupont Vertrel MCA)
[2] mmHg @ 25°C
[3] cps @ 25°C
[4] cal/g @ boiling point
[5] CFC-11 = 1.0
[6] GWP - 100 year ITH, CO_2 = 1.0
[7] 4.1 - 3M HFE-7100, 0.01 trans-1, 2-dichloroethylene

3M HFE-71DE Material Specifications

Methyl Nonafluorobutyl Ethers[1]	50% by weight
Trans-1,2-dichloroethylene	50% by weight
Appearance	Clear, colorless

[1] 3M HFE-7100 ($C_4F_9OCH_3$) consists of two inseparable isomers with essentially identical properties. These are $(CF_3)_2CFCF_2OCH_3$ (CAS No. 163702-08-7) and $CF_3CF_2CF_2CF_2OCH_3$ (CAS No. 163702-07-6).

(continued)

Table 3.64: (continued)

Regulatory Status

The U.S. Environmental Protection Agency (EPA) has completed its Pre-Manufacturing Notification (PMN) review and has permitted 3M to commercialize 3M™ HFEs immediately. Both components of 3M HFE-71DE are TSCA listed. 3M is pursuing an "Acceptable" listing for Methyl Nonafluorobutyl Ethers under the EPA's Significant New Alternative Policy (SNAP) program. Trans-1,2-dichloroethylene is approved under SNAP for use as a cleaning solvent.

As a result of its lower toxicity, trans-1,2-dichloroethylene is far less regulated in its use compared to "chlorinated solvents." The only regulations affecting 3M HFE-71DE due to the presence of trans are VOC emissions and reporting requirements if it is emitted into water or if a spill of 2000 lb or more occurs. Trans is not considered a Hazardous Air Pollutant and is not subject to annual reporting requirements. The following table lists the regulations covering trans compared to chlorinated solvents.

Regulations on Chlorine-Containing Solvents

Regulation	Trans-1,2-dichloro ethylene	Trichloro ethylene	Perchloro ethylene	Methylene Chloride
VOC Designation	Yes	Yes	Yes	No
Hazardous Waste	Yes for pure trans (no for 3M™ HFE-71DE)	Yes	Yes	Yes
Reportable Qty for Accidental Release	1,000 lbs (2,000 lbs in 3M HFE-71DE)	100 lbs	100 lbs	1,000 lbs
Regulated if Emitted into Water	Yes	Yes	Yes	Yes
Hazardous Air Pollutant	No	Yes	Yes	Yes
Annual Reporting (EPCRA 313) (SARA)	No	Yes	Yes	Yes
OSHA List of toxins/carcinogens	No	Yes	Yes	Yes
NJ or CA Hazardous Lists	No	Yes	Yes	Yes

<u>Typical Physical Properties of HFE L-13938</u>

Boiling Point (°C)	60
Freezing Point (°C)	-135
Flash Point (°C)	None
Solubility for water (ppm)	95
Solubility in water (ppm)	<10

<u>Thermal Transport Properties of HFE L-13938</u>

	@ 0°C	@ -40°C
Density (gm/ml)	1.54	1.63
Specific Heat (J/Kg °C)	1133	1053
Viscosity (cSt)	.60	1.07
Thermal Conductivity (W/m °C)	.074	.082

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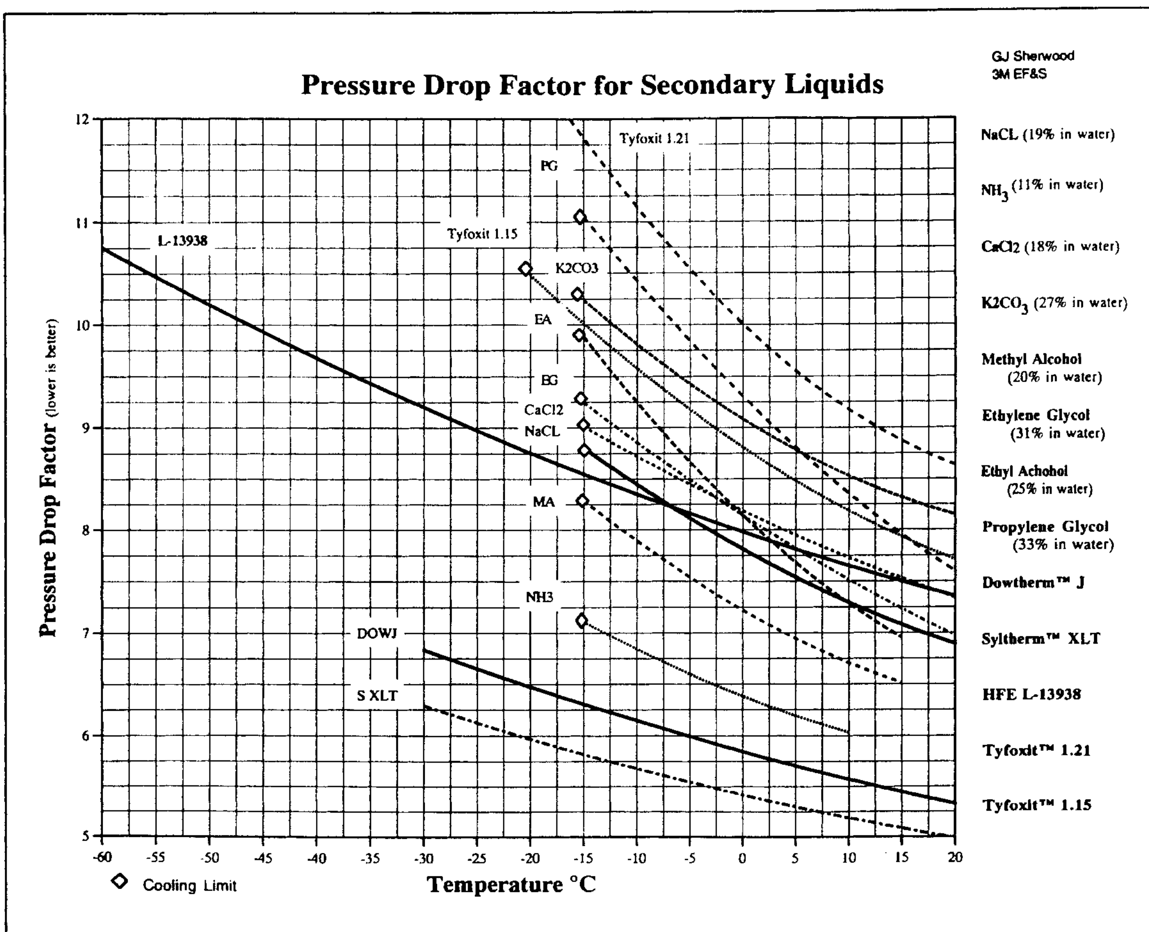
Table 3.64: (continued)

Environmental Properties of HFE L-13938

Ozone Depletion Potential (ODP)	**0**	(CFC11 = 1)
Volatile Organic Compound (VOC)	**No**	
Atmospheric Lifetime	**4.0 years**	
GWP (IPCC 1994)	**500**	(CO_2 = 1, 100th year)
HGWP	**0.09**	(CFC11 = 1)

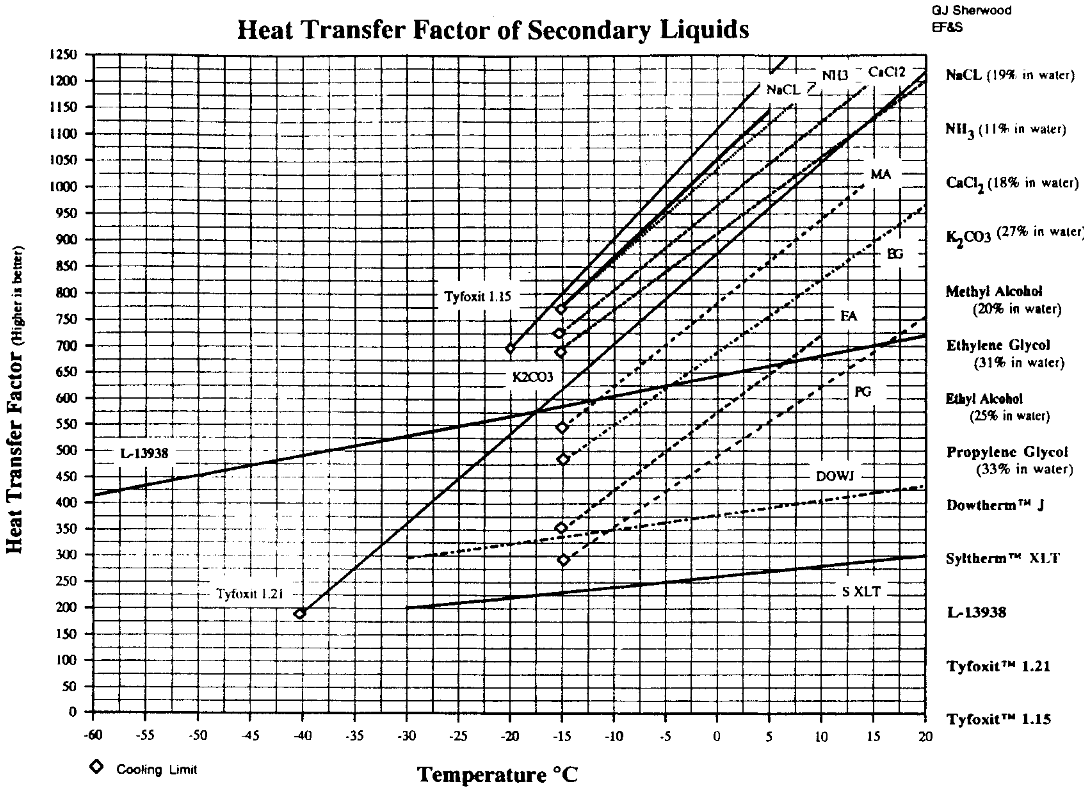
Toxicological Properties of HFE L-13938

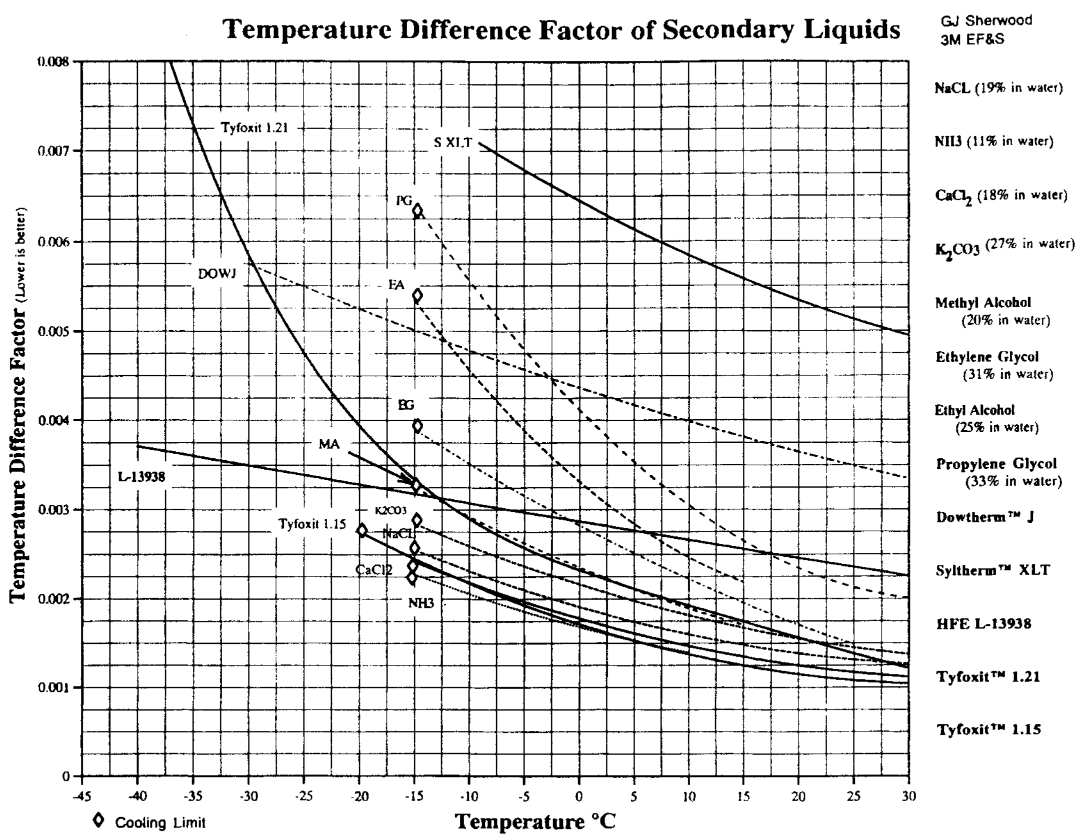
Oral	Practically non-toxic orally
Eye Irritation	No irritation
Skin Irritation	No Irritaiton
Skin Sensitization	Not a Skin Sensitizer
Inhalation	No observable effects at 10,000 ppm
ALC	>100,000 ppm (4hrs)
Chronic Toxicity	In Progress



(continued)

Table 3.64: (continued)

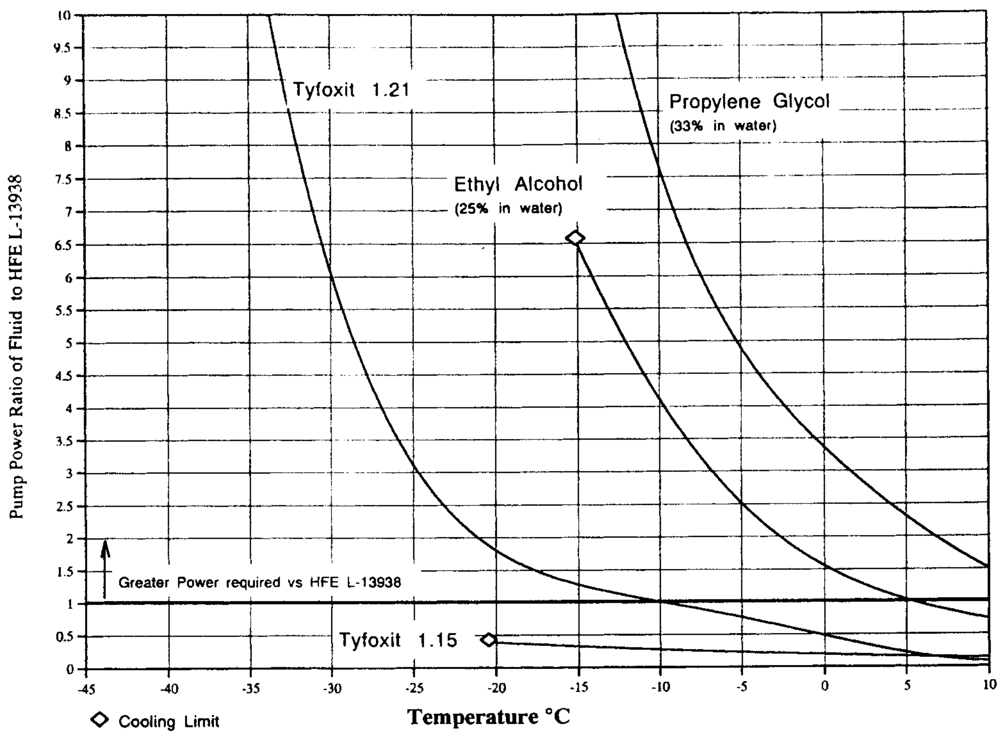




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Table 3.64: (continued)

Theoretical Specific Pump Power Requirements



Physical Properties of HFEs

Property	$C_4F_9OCH_3$ (HFE A)	$C_4F_9OC_2H_5$ (HFE B)	$CF_2ClCFCl_2$ (CFC-113)	CH_3CCl_3 (TCA)
Boiling Point (°C)	60	73	48	74
Freezing Point (°C)	-135	-117	-35	-39
Flash Point (°C)	None	None	None	None
Solubility for Water (ppm)*	95	92	170	266
Solubility in Water (ppm)*	< 10**	< 10**	110	700

* @ 25°C
** detection limit for material

Physical Properties of HFEs

Property (@23°C)	$C_4F_9OCH_3$ (HFE A)	$C_4F_9OC_2H_5$ (HFE B)	$CF_2ClCFCl_2$ (CFC-113) (@25°C)	CH_3CCl_3 (TCA)
Liquid Density (g/ml)	1.50	1.43	1.56	1.32
Viscosity (cp)	0.61	0.61	0.68	0.83
Surface Tension (dynes/cm)	13.6	13.6	17.3	25.1
Heat of Vaporization (cal/g)	30	30	35	58
Specific Heat (cal/g/°C)	0.28	0.29	0.22	0.24

(continued)

Table 3.64: (continued)

Environmental Properties of HFEs

Property	$C_4F_9OCH_3$ (HFE A)	$C_4F_9OC_2H_5$ (HFE B)	$CF_2ClCFCl_2$ (CFC-113)	CH_3CCl_3 (TCA)
ODP *(CFC-11 = 1)*	0	0	0.8	0.1
VOC	No	No	No	No
Atmospheric Lifetime *(years)*	5.5	1.2	110	6.1
GWP *(CO2=1, 100 Year ITH)*	500	110	4500	100
HGWP *(CFC-11 = 1)*	0.12	0.03	1.4	0.02

Key Material Compatibilities with HFEs

Compatible with:

Metals
- Aluminum
- Copper*
- Carbon Steel
- 302 Stainless Steel

Elastomers
- Natural
- Neoprene
- Urethane
- EPDM
- SBR
- Nitrile

Plastics
- Acrylic
- Polyethylene
- Polypropylene
- PVC
- PMMA
- Polycarbonate

Exceptions:
- Some swelling of PTFE
- Significant swelling of Silicone Rubber
- * Some surface oxidation during heat aging

One week exposures at boiling temperature

HFE Toxicity Evaluations – Status

- **Phase 1 - (Acute) Tests**

Oral	Practically non-toxic orally
Inhalation	No observable effects at 10,000 ppm
ALC of C_4F_9-O-CH_3	> 100,000 ppm (4 hr)
ALC of C_4F_9-O-C_2H_5	> 50,000 ppm (4 hr)
Skin Irritation	No Irritation
Skin Sensitization	Test In Progress
Eye Irritation	No Irritation
Ames Assay	In Preparation

- **Phase 2 - (Advanced) Tests** — All In Preparation
  - Ecotoxicity
  - Cardiac Sensitization
  - Inhalation Range Finding & Developmental Toxicity
  - 90 Day Inhalation

Hydrocarbon Solvency

Solubility for dodecane ($C_{12}H_{26}$)

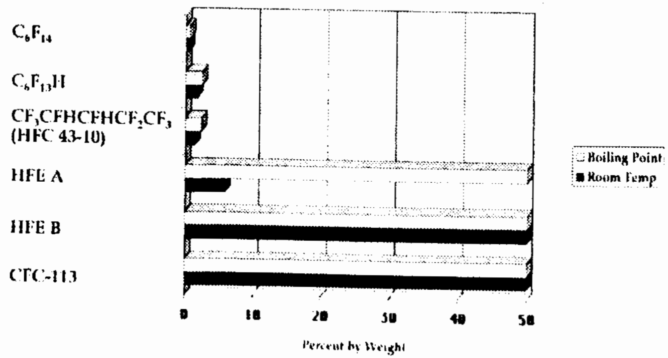
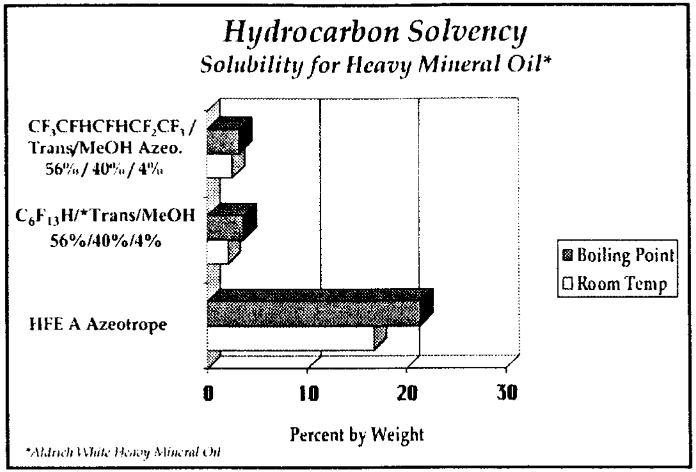


Table 3.64: (continued)



*Trans = Trans 1,2-dichloroethylene

Stability of HFEs

Hydrolytic Stability

	$C_4F_9OCH_3$ (HFE A)	$C_4F_9OC_2H_5$ (HFE B)	$CF_2ClCFCl_2$ (CFC-113)	C_6F_{14}
HF Generation Rate @ Boiling Point (µg/g-hr)	0.46	0.07	0.02	< 0.01
HF Generation Rate @ 110°C (µg/g-hr)	0.67	0.22	0.44	< 0.01

- Samples heated for 16 hours in sealed tubes containing 0.1 M aqueous sodium acetate
- Analyzed using coulometric titration employing fluoride ion specific electrode

HFEs vs. HFCS

◆ *Higher Hydrolytic Stability*

Compound	HF Generation Rate @ Boiling Point (µg/g/-hr)	HF Generation Rate @ Boiling Point + 50 °C (µg/g/-hr)
$C_4F_9OCH_3$ (HFE A)	0.46	0.67
$C_4F_9OC_2H_5$ (HFE B)	0.07	0.22
$C_5F_{11}CH_3$	1.31	18.9

- Samples heated for 16 hours in sealed tubes containing 0.1 M aqueous sodium acetate
- Analyzed using coulometric titration employing a fluoride specific electrode

HFEs vs. HFCs

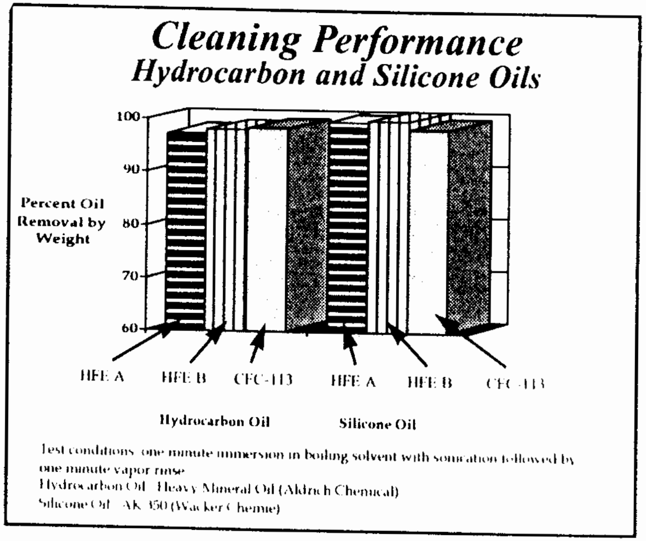
◆ *Shorter Atmospheric Lifetimes*

HFE vs HFC	Ratio of Estimated Lifetimes* (HFE/HFC)
CF_3-O-CH_3 vs CF_3CH_3	0.03
C_2F_5-O-CH_3 vs $C_2F_5CH_3$	0.13
C_3F_7-O-CH_3 vs $C_3F_7CH_3$	0.20
C_4F_9-O-CH_3 vs $C_4F_9CH_3$	0.25

*From calculated reaction rates with hydroxyl radical

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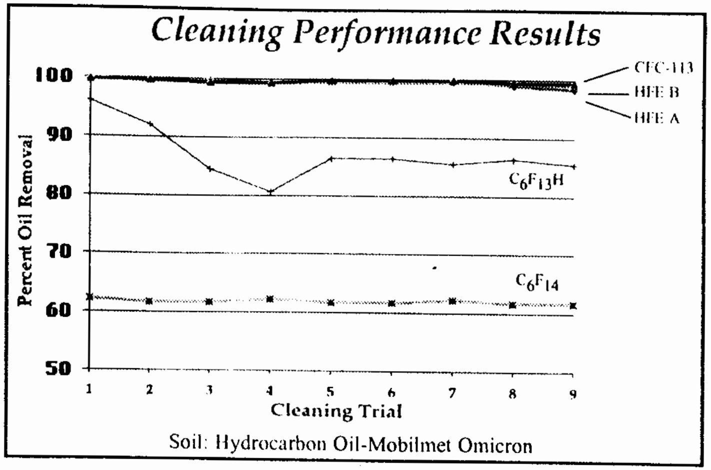
Table 3.64: (continued)



HFEs vs. HFCs

◆ *Lower Global Warming Potentials*

Compound	Global Warming Potential (CO_2 = 1, 100 year ITH)
$C_4F_9OC_2H_5$ (HFE B)	110
$C_4F_9OCH_3$ (HFE A)	500
$CF_3CFHCFHC_2F_5$ (HFC-43-10mee)	1000
CF_3CH_2F (HFC-134a)	1200
CF_3CFHCF_3 (HFC-227ea)	2050



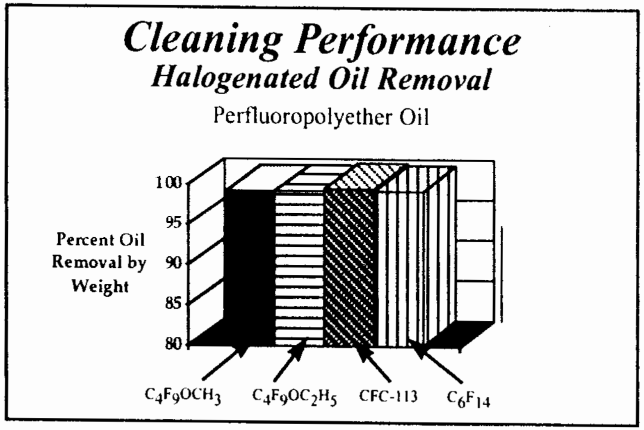


Table 3.64: (continued)

Cleaning Performance Results - As An AVD™ Rinsing Agent

Percent Soil Removal

	$C_4F_9OCH_3$	$C_4F_9OC_2H_5$	CFC-113
Heavy Oil	99.9	100.0	100.0
Flux	100.0	100.0	80.8

All materials except CFC-113 employed a 1 minute immersion in Petroferm Solvating Agent 24 with sonication followed by 30 seconds immersion rinsing at the boiling point

Heavy Oil - Duo Seal Pump Oil (Sargent-Welch Scientific Co.)
Solder Flux - Alpha 611

AVD is a trademark of Petroferm Inc.

Solvency of HFEs

Compound	Kauri-Butanol Value*
CFC-113	32
1,1,1-trichoroethane	123
C_6F_{14}	0
$C_4F_9OCH_3$	10
$C_4F_9OCH_3$ Azeotrope	27
Solvating Agent 24	>150

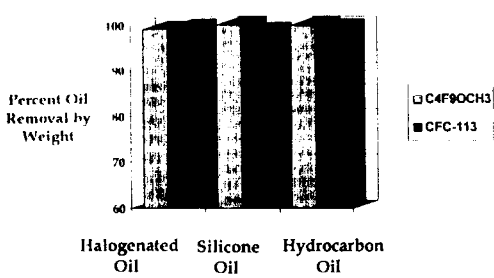
* per ASTM D 1133-86

HFE Cleaning Spectrum

Cleaning System :

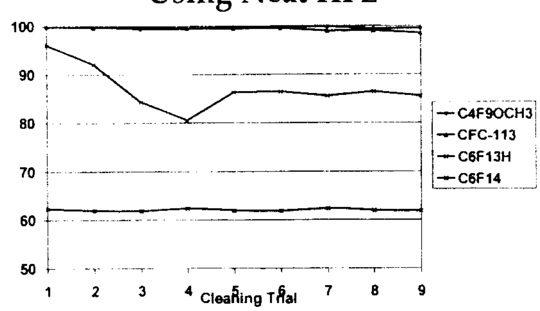
Neat HFE →	HFE Azeotrope →	HFE Co-Solvent Cleaning
Soils:		
Light Oils Halogenated Compounds Particulates	Medium Weight Oils Silicone Oils Lubricants Release Agents Hydraulic Fluids	Heavy Oils Hydrocarbon Greases Silicone Greases Buffing Compounds Polishing Agents Flux Residue

Cleaning Performance Using Neat HFE



Test conditions: one minute immersion in boiling solvent with sonication followed by one minute vapor rinse.
Halogenated Oil: Krytox 157FSM (DuPont)
Silicone Oil: AK 350 (Wacker Chemie)
Hydrocarbon Oil: Mobilmet Omicron

Cleaning Performance Using Neat HFE



Conditions: one minute immersion in boiling solvent with sonication
Soil: Hydrocarbon Oil - (Mobilmet Omicron)

(continued)

Table 3.64: (continued)

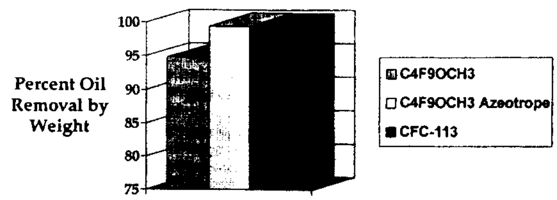
Neat HFE Cleaning Performance
α - Site Testing Results

Examples of Components Successfully Cleaned using Neat HFEs

Customer Part	Soil Removed	Result
Medical Device	Light Hydrocarbon Oil	Meets Customer Requirements
Gyroscope	Brominated Flotation Fluid	Meets Customer Requirements
Diskette Shutter	Light Silicone Oil*	Meets Customer Requirements

* Cleaned in Vapor Phase

Cleaning Performance
Using an HFE Azeotrope



Test conditions: one minute immersion in boiling solvent with sonication
Hydrocarbon Oil: Metalub 525

Cleaning Performance as a
Co-Solvent Rinsing Agent

Soil Removal (Percent by Weight)

	$C_4F_9OCH_3$	CFC-113	CFC-113/ EtOH
Heavy Oil	99.9	100.0	-----
RMA Flux	100.0	80.8	100.0

Use of HFE employed a 1 minute immersion in Petroferm Solvating Agent 24 with sonication followed by 30 seconds immersion rinsing at the boiling point
CFC-113 used a 1 minute immersion with sonication at the boiling point.

Heavy Oil - Duo Seal Pump Oil (Sargent-Welch Scientific Co.)
Solder Flux - Alpha 611 (Alpha Metals, Inc.)

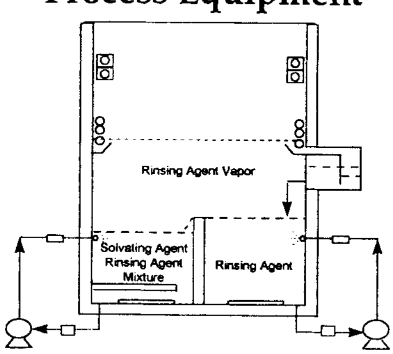
HFE Azeotrope Cleaning Performance
α - Site Testing Results

Examples of Components Successfully Cleaned using an HFE Azeotrope:

Customer Part	Soil Removed	Results
Optical Component	Medium Hydrocarbon Oils*	Meets Customer Requirements
Medical Component	High MW Silicone Oil	Meets Customer Requirements
Metal Component	Hydraulic Oil	Meets Customer Requirements

* Cleaned in Vapor Phase

Co-Solvent Cleaning
Process Equipment



HFE Co-Solvent Cleaning Performance
α - Site Testing Results

Examples of Components Successfully Cleaned using an HFE Co-Solvent System:

Customer Part	Soil Removed	Results
Aerospace Component	Hydrocarbon and Fluorinated Greases	Meets Customer Requirements
Assembled Bearing	High MW Hydrocarbon Grease	Meets Customer Requirements
Electrical Connector	RMA Flux	Meets Customer Requirements

(continued)

Table 3.64: (continued)

Summary: Performance of Hydrofluoroethers in Cleaning Applications

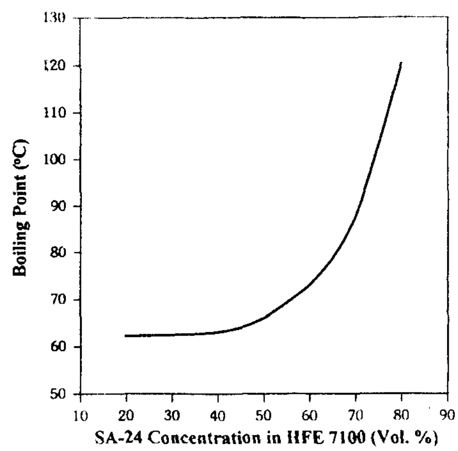
- Physical Properties Which Closely Match ODSs
- Very Good Environmental Profile
  - Not Precursors to Photochemical Smog (VOCs)
  - Zero Ozone Depletion Potential
  - Short Atmospheric Lifetimes
  - Low Global Warming Potentials
- Solvency for a Number of Soils
- Effective Cleaning Agents in a Variety of Processes

Solubility (at 25°C) of Various Solutes in PFC, HFC, and HFE

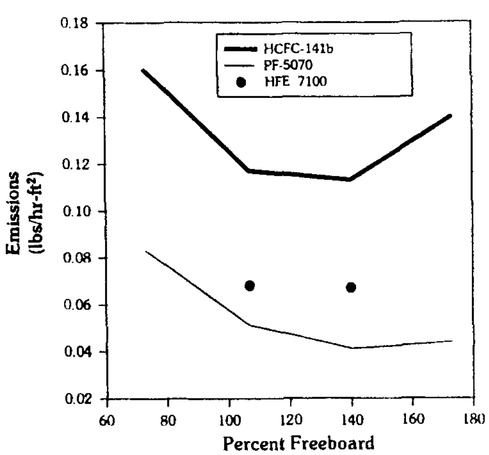
Solute	Solubility (percent) in			
	PFC[1]	HFC[2]	Methyl HFE[3]	Ethyl HFE[4]
IPA	<1	Miscible	Miscible	Miscible
Kerosene	<1	2	5	Miscible
Mineral oil	<1	<1	<1	<1
Limonene	<1	3.5	20	Miscible
AVD 19	<1	Miscible	Miscible	Miscible

(1) C_6F_{14} (Perfluorohexane)
(2) $C_6F_{13}H$ ("1-H Perfluorohexane")
(3) $F_9C_4OCH_3$
(4) $F_9C_4OC_2H_5$

Boiling Point of HFE/SA-24 Mixtures



Idling Emissions vs. Freeboard

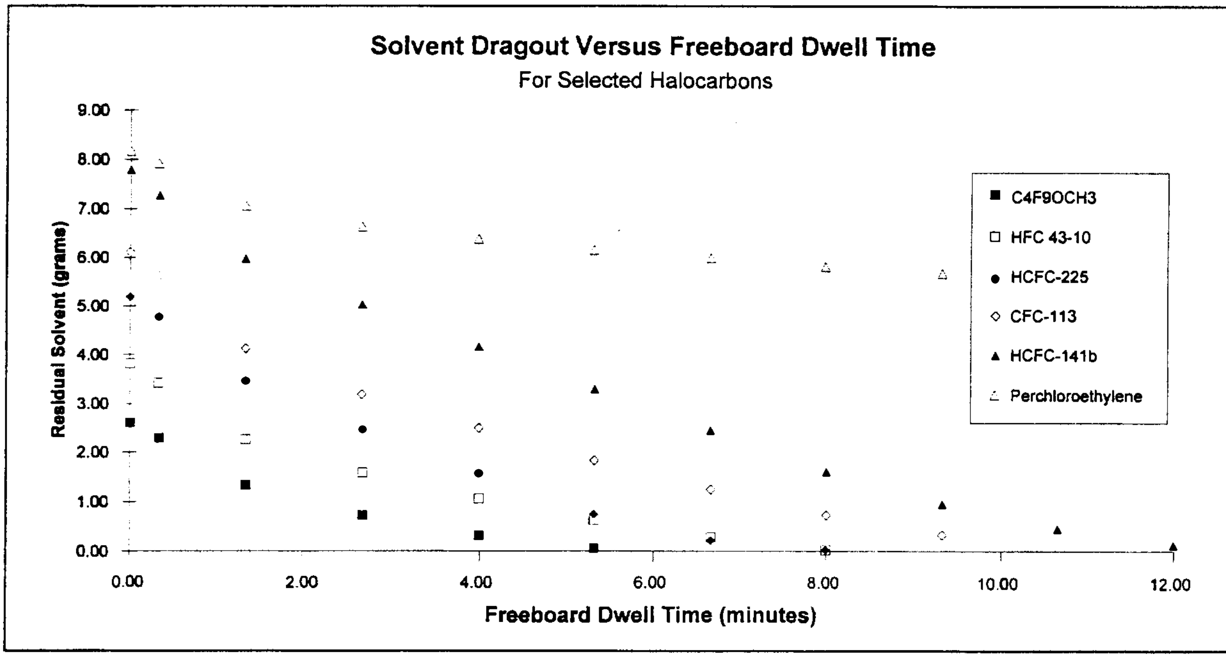


Selected Parts and Soils Cleaned

Parts	Soils
Ball bearings	Cutting Oil
Ball bearing assemblies	EP Grease
Contact lens mounts	RMA flux
Fuel injector components	Wax
Graduated capillary spacing test assembly	
Heat exchangers	
Printed circuit assemblies	

(continued)

Table 3.64: (continued)



HFE Toxicity Evaluation - Status

◆ **Phase 1 - Acute Tests**	
Inhalation	**No observable effects at 10,000 ppm**
ALC of C_4F_9-O-CH_3	**> 100,000 ppm (4 hr)**
ALC of C_4F_9-O-C_2H_5	**> 50,000 ppm (4 hr)**
Oral	**Practically non-toxic orally**
Eye Irritation	**No Irritation**
Skin Irritation	**No Irritation**
Skin Sensitization	**Not a Skin Sensitizer**
◆ **Phase 2 - Advanced Tests**	**In Progress**
Ecotoxicity	
Inhalation Range Finding (28 day)	
Developmental Toxicity	
Cardiac Sensitization	
90 Day Inhalation	

(continued)

Table 3.64: (continued)

Key Material Compatibilities with HFEs

Compatible after one hour exposure at boiling temperature:

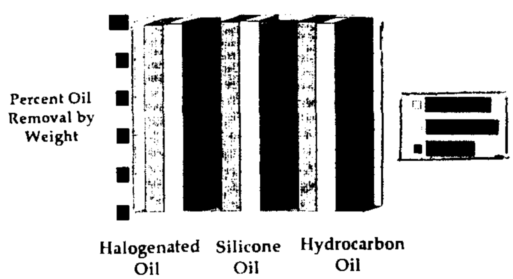
Metals	Plastics	Elastomers
Aluminum	Acrylic	Natural Rubber
Copper	Polyethylene	Butyl Rubber
Carbon Steel	Polypropylene	Nitrile Rubber
302 Stainless Steel	Polycarbonate	EPDM
Brass	Polyester	
Zinc	Nylon	
Molybdenum	Epoxy	
Tantalum	PMMA	
Titanium	PVC	
Tungsten	PET	
Cu/Be Alloy C172	ABS	
Magnesium Alloy AZ31B		

Exceptions: Some swelling of PTFE and Silicone Rubber.
Some surface oxidation of copper during heat aging.

Applications for HFEs

- Cleaning Solvents
  - Metals & Precision Cleaning
  - Electronics Cleaning
- Carrier Solvents
- Drying Fluid
- Heat Transfer Fluid
- Clean Extinguishing Agents

Cleaning Performance Using Pure HFE



Test conditions: one minute immersion in boiling solvent with sonication followed by one minute vapor rinse.
Halogenated Oil: Krytox 157FSM (DuPont)
Silicone Oil: AK 350 (Wacker Chemie)
Hydrocarbon Oil: Mobilmet Omicron

Hydrofluoroethers
A Family of New Fluorinated Solvents

- Cover a Range of Boiling Points
- Effective Cleaning Agents
- Good Materials Compatibility and High Stability
- Are Not Precursors to Photochemical Smog (VOCs)
- Have Zero Ozone Depletion Potential
- Short Atmospheric Lifetimes
- Low Global Warming Potentials
- With Favorable Toxicity Results
- Additional New Materials Under Development

Nitroparaffins

Table 4.1: Angus Nitroparaffins *(34)*

Nitromethane CH_3NO_2
CAS Registry No. 75-52-5

Nitroethane $CH_3CH_2NO_2$
CAS Registry No. 79-24-3

1-Nitropropane $CH_3CH_2CH_2NO_2$
CAS Registry No. 108-03-2

2-Nitropropane $CH_3CH(NO_2)CH_3$
CAS Registry No. 79-46-9

Specifications

	Nitromethane	Nitroethane	1-Nitropropane	2-Nitropropane
Purity, % by wt (min.)*	98.0	98.0	98.5	96.0
Total nitroparaffins, % by wt (min.)*	99.0	99.0	99.0	99.0
Specific gravity at 25/25°C	1.124-1.135	—	—	—
Acidity as acetic acid, % by wt (max.)	0.1	—	0.2	0.1
Water, % by wt (max.)	0.1	0.2	0.1	0.1
Color, APHA (max.)	20	20	20	20

*Determined by gas chromatography

Typical Properties of Commercial-Grade Nitroparaffins

	Nitromethane	Nitroethane	1-Nitropropane	2-Nitropropane
Distillation range at 1 atm (90% min.), °C	100-103	112-116	129-133	119-122
Vapor density (air=1)	2.11	2.58	3.06	3.06
Change of density with temperature, 0-50°C, g/(ml·°C)	0.0014	0.0012	0.0011	0.0011
Weight per U.S. gallon at 68°F, lb	9.4	8.75	8.35	8.24
Flash point, Tag open cup, °F	112	106	120	100
Tag closed cup, °F	96	87	96	82
Lower limit of flammability, % by vol (at °C)	7.3(33)	3.4(30)	2.2(34)	2.5(27)
Ignition temperature, °C	418	414	420	428
Evaporation rate (*n*-butyl acetate=100)	139	121	88	110
Evaporation number (diethyl ether=1)	9	11	16	10

Physical Properties of the Nitroparaffins

	Nitromethane	Nitroethane	1-Nitropropane	2-Nitropropane
Molecular weight (calcd.)	61.041	75.068	89.095	89.095
Boiling point at 760 mmHg, °C	101.20	114.07	131.18	120.25
Vapor pressure at 25°C, mmHg	36.66	20.93	10.23	18.0
Freezing point, °C	−28.55	−89.52	−103.99	−91.32
Density at 20°C, g/ml	1.138	1.051	1.001	0.988
at 30°C, g/ml	1.124	1.039	0.991	0.977
Coefficient of expansion per °C	0.00122	0.00112	0.00101	0.00104
per °F	0.00068	0.00062	0.00056	0.00058
Refractive index, n_D, at 20°C	1.38188	1.39193	1.40160	1.39439
at 30°C	1.37738	1.38754	1.39755	1.39028
Surface tension at 20°C, dynes/cm	37.48	32.66	30.64	29.87
Viscosity at 20°C, cp	0.647	0.677	0.844	0.770
at 30°C, cp	0.576	0.602	0.740	0.677

(continued)

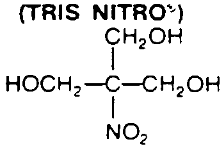
Table 4.1: (continued)

Physical Properties of the Nitroparaffins

	Nitromethane	Nitroethane	1-Nitropropane	2-Nitropropane
Heat of combustion (liq.) at 25°C, kcal/mole	—169.3	—325.6	—481.9	—478.0
Heat of vaporization (liq.) at 25°C, kcal/mole	9.147	9.94	10.37	9.88
at bp, kcal/mole	8.23	9.08	9.19	8.79
Heat of formation (liq.) at 25°C, kcal/mole	—27.03	—33.9	—40.15	—43.2
Specific heat at 25°C, cal/(mole·°C)	25.33	33.10	41.96	41.87
at 25°C, cal/(g·°C)	0.415	0.441	0.471	0.470
Dielectric constant at 30°C	35.87	28.06	23.24	25.52
Dipole moment, μ, gas, Debye units	3.50	3.58	3.72	3.73
liquid, Debye units	3.17	3.19	—	—
Aqueous azeotrope, bp, °C	83.59	87.22	91.63	88.55
% NP by wt	76.4	71.0	63.5	70.6
pH of 0.01*M* aqueous solution	6.4	6.0	6.0	6.2
Solubility in water at 20°C, % by wt	10.5	4.6	1.5	1.7
at 25°C, % by wt	11.1	4.7	1.5	1.7
at 70°C, % by wt	19.3	6.6	2.2	2.3
Solubility of water in NP at 20°C, % by wt	1.8	0.9	0.6	0.5
at 25°C, % by wt	2.1	1.1	0.6	0.5
at 70°C, % by wt	7.6	3.0	1.7	1.6
Hydrogen bonding parameter, γ	2.5	2.5	2.5	2.5
Solubility parameter, δ	12.7	11.1	10.7	10.7

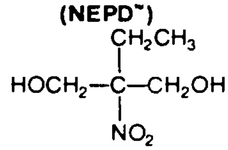
Table 4.2: Angus Nitro Alcohols *(34)*

(TRIS NITRO®)



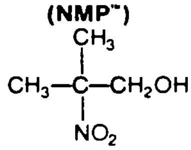
2-Nitro-2-hydroxymethyl-1,3-propanediol or
Tris (hydroxymethyl)nitromethane
[CAS Reg. No. 126-11-4]

(NEPD™)



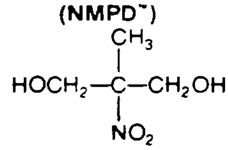
2-Nitro-2-ethyl-1,3-propanediol
[CAS Reg. No. 597-09-1]

(NMP™)



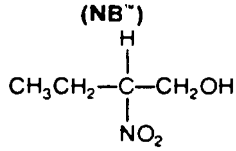
2-Nitro-2-methyl-1-propanol
[CAS Reg. No. 76-39-1]

(NMPD™)



2-Nitro-2-methyl-1,3-propanediol
[CAS Reg. No. 77-49-6]

(NB™)



2-Nitro-1-butanol
[CAS Reg. No. 609-31-4]

(continued)

Table 4.2: (continued)

Product Specifications*

Solid Form	Melting Pt., °C (Min.)	Water % By wt. (Max.)	Free Formaldehyde % by wt. (Max.)	1% by wt. Aq. Solution	
				pH	Color (max.)
NMP (pellets) †	86-90	0.5	0.06	-	-
TRIS NITRO (solid)	-	-	-	2.0-5.0	5 Gardner

† 23.50% (min.) by wt. of bound formaldehyde, 1.5% (max.) by wt. of stearic acid.

Aqueous Solutions	Assay, % by wt. (min.)	Free Formaldehyde % by wt. (max.)	pH, 20% by wt. Aq. Solution	Color, Gardner, (max.)
TRIS NITRO 25%	25.0	1.0	2.0 - 5.0	5
TRIS NITRO 37.5%	37.5	1.0	—	—
TRIS NITRO 50%	50.0	1.0	2.0 - 4.5	5
NEPD Aqueous	55.0	1.0	2.0 - 5.0	5
NMP Concentrate	60.0	0.5	2.5 - 5.1	1

* Test methods available upon request

Physical Properties of Purified Materials

	NMP	NMPD	NEPD	NB	TRIS NITRO
Molecular weight (calc.)	119.12	135.12	149.15	119.12	151.12
Melting point, °C	90	∿160	∿150	-47 - -48	175-176 decomp.
Boiling pt., °C at 10 mmHg	—	decomp.	decomp.	105	—
at 15 mmHg	94	—	—	—	
pH of 0.1 M soln at 20°C	5.1	5.4	5.5	4.5	5.0
Density at 25°C, g/mL	—	—	—	1.129	—
Wt. per gallon, lb at 68°F	—	—	—	9.43	—
Coefficient of expansion per °C	—	—	—	0.00076	—
Refractive index, n_d at 20°C	—	—	—	1.444	—
Surface tension at 20°C dynes/cm	—	—	—	37.7	—
Solubility in 100 mL of water at 20°C (g)	350	80	400	54	220

Table 4.3: Angus Primary Amino Alcohols *(34)*

AB®
2-Amino-1-butanol
CAS Registry No. 96-20-8
$CH_3CH_2CHCH_2OH$
|
NH_2

AMPD™
2-Amino-2-methyl-1,3-propanediol
CAS Registry No. 115-69-5
CH_3
|
$HOCH_2$-C-CH_2OH
|
NH_2

AMP
2-Amino-2-methyl-1-propanol
CAS Registry No. 124-68-5
CH_3
|
H_3C-C-CH_2OH
|
NH_2

AEPD®
2-Amino-2-ethyl-1,3-propanediol
CAS Registry No. 115-70-8
CH_2CH_3
|
$HOCH_2$-C-CH_2OH
|
NH_2

TRIS AMINO®
Tris(hydroxymethyl)aminomethane
CAS Registry No. 77-86-1
CH_2OH
|
$HOCH_2$-C-CH_2OH
|
NH_2

(continued)

Table 4.3: (continued)

Typical Properties

	2-Amino-2-methyl-1-propanol AMP Regular®	2-Amino-2-methyl-1-propanol AMP-95®	2-Amino-1-butanol AB	2-Amino-2-ethyl-1,3-propanediol AEPD	2-Amino-2-methyl-1,3-propanediol AMPD	Tris(hydroxymethyl)-aminomethane TRIS AMINO Crystals
Neutral Equivalent	88.5-91	93-97	88.5-91	124 (max.)	103-107	121-122
Water, % by wt. (max.)	0.8	5.8	0.5	3.8	0.5	0.5
Melting point, °C (min.)	—	—	—	—	100	160
Color (max.)	20 APHA	20 APHA	100 APHA	—	—	—
Color of 20% aqueous solution (max.)	—	—	—	2 Gardner	50 APHA	40 APHA

Physical Properties of Purified Materials

	2-Amino-2-methyl-1-propanol	2-Amino-1-butanol	2-Amino-2-ethyl-1,3-propanediol	2-Amino-2-methyl-1,3-propanediol	Tris(hydroxymethyl)-aminomethane
Molecular weight (calcd.)	89.14	89.14	119.17	105.14	121.14
Boiling point at 760 mm Hg, °C	165	178	—	—	—
Boiling point at 10 mm Hg, °C	—	—	152-153	151-152	219-220
Melting point, °C	30-31	-2	37.5-38.5	109-111	171-172
Specific gravity at 40/40°C	0.928	—	1.101	—	—
pH of 0.1*M* aqueous solution at 20°C	11.3	11.1	10.8	10.8	10.4
Solubility in water at 20°C, g/100 mL	miscible	miscible	miscible	250	80
Weight per gallon at 20°C, lb	7.78	7.86	9.15	—	—
pK_a at 25°C	9.72	9.52	8.80	8.76	8.03

Additional Properties of AMP

	AMP Regular	AMP-95
Viscosity at 10°C, cps	—	561
25°C, cps	—	147
30°C, cps	102	—
50°C, cps	24	—
70°C, cps	9	—
90°C, cps	4	—
Vapor pressure at 100°C, mm Hg	59	—
150°C, mm Hg	457	—
Specific gravity at 25/25°C	—	0.942
Coefficient of expansion per °C	0.00095	0.00096
Refractive index, n_D, at 20°C	1.449	—
Heat of vaporization at 110°C, kcal/mole	13.2	—
130°C, kcal/mole	12.5	—
150°C, kcal/mole	12.3	—
165°C, kcal/mole	12.1	—
Heat of dissociation at 25°C, kcal/mole	1.29	—

Table 4.4: Angus DMAMP-80 *(34)*

80% 2-Dimethylamino-2-Methyl-1-Propanol Solution CAS Reg. No. 7005-47-2

2-Dimethylamino-2-methyl-1-propanol, a member of the family of Angus amino alcohols, is the tertiary-amine homolog of 2-amino-2-methyl-1-propanol (AMP). 2-Dimethylamino-2-methyl-1-propanol is available as DMAMP-80 which contains about 20% by weight water.

(continued)

Table 4.4: (continued)

Typical Properties

The following are typical properties of DMAMP-80; they are not to be considered product specifications.

Neutral Equivalent	~148
Specific Gravity @ 25/25°C	0.95
Weight per Gallon @ 25°C	7.9 lb
Flash Point, Tag Open Cup	150°F/66°C
Tag Closed Cup	153°F/67°C
Freezing Point	−4°F/−20°C
Boiling point @ 760 mm Hg	208°F/~98°C
Viscosity @ 25°C, Gardner	A-A_2
pH of 0.1 *N* Aqueous Solution	11.6

Table 4.5: Industrial Amines Ranked in Order of Decreasing Base Strength *(34)*

Amine	pKa (20° C)	Molecular Weight	Vapor Pressure (mm Hg)	Boiling Point °C (1 atm.)	Flash Point (°F COC[1])
Cyclohexylamine	10.79	99	95	135	90
Triethylamine	10.74	101	57	90	20
Diethylaminoethanol (DEAE)	9.87	117	1.0	163	140
→ **AMINOMETHYLPROPANOL (AMP-95™)**	9.82	89	0.7	165	172
→ **AMINOBUTANOL (AB™)**	9.52	89	1.0	178	193[2]
Monoethanolamine (MEA)	9.44	61	0.36	171	195
Monoisopropanolamine (MIPA)	9.40	75	0.6	160	165
Dimethylethanolamine (DMEA)	9.31	89	4.0	134	105
Ammonia (29.4%)	9.24	17	357	N/A	—
Diethanolamine (DEA)	8.88	105	<0.01	269	300
→ **AMINOETHYLPROPANEDIOL (AEPD®)**	8.80	119	<0.01	153[3]	>200
→ **AMINOMETHYLPROPANEDIOL (AMPD™)**	8.76	105	<0.01	152[3]	N/A
Diisopropanolamine (DIPA)	8.70	133	0.02	250	250
Morpholine	8.43	87	10.08	129	100
→ **TRIS(HYDROXYMETHYL)AMINO-METHANE (TRIS AMINO®)**	8.03	121	<0.01	220[3]	N/A
Triisopropanolamine (TIPA)	7.86	191	0.0008	305	320
Triethanolamine (TEA)	7.77	149	<0.01	335	365

[1] Cleveland Open Cup
[2] Tag Closed Cup
[3] 10 mm Hg

Table 4.6: Comparing Amines for Safety *(34)*

	Acute Oral LD_{50}	Acute Skin Penetration LD_{50} (Rabbits)	Eye Injury Rabbits	Primary Skin Irritation	Threshold Limit	Flash Point (Tag Closed Cup)	DOT Hazard Label Required
AMP	2.9 g/kg (Rats)	No deaths at 2 g/kg	Severe	Severe	None Est.	172°F	None (Combustible)*
Monoethanolamine (MEA)	2.1 g/kg (Rats)	1.0 g/kg	Severe	Corrosive	3 PPM	185°F	Corrosive
Diethylaminoethanol (DEAE)	1.4 g/kg (Rats)	1.26 g/kg	Severe	Severe	10 PPM	140°F	None (Combustible)*
Dimethylaminoethanol (DMAE)	1.3 g/kg (Rats)	1.37 g/kg	Severe	Severe	None Est.	105°F	None (Combustible)*
Morpholine	1.0 g/kg (Rats)	0.5 g/kg	Severe	Corrosive	20 PPM	95°F	Flammable
Triethylamine	0.46 g/kg (Rats)	0.42 g/kg	Severe	Trace	25 PPM	17°F	Flammable
Triethanolamine	8.7 g/kg (Rats)	22.5 g/kg Killed 0 of 5	Severe	Minor	None Est.	>200°F	None

*** Combustible Materials Require Placarding Only For Bulk Shipments.**

Table 4.7: NIPAR 640 *(34)*

Typical Properties of NiPar 640

Distillation range at 760 mmHg (90% min.), °C	112-133
Freezing point, °C	∿-100
Vapor pressure at 20°C, mmHg	13
Density of Vapors (air=1) (calcd.)	2.6-3.0
Specific gravity at 20/20°C	∿ 1.01
Weight per U.S. gallon at 20°C, lb	∿ 8.4
Coefficient of expansion per °C	0.001
Flash point, Tag closed cup, °F	94
Evaporation rate, by vol (*n*-butyl acetate=100)	100
Solubility in water at 20°C, % by wt	2.6

Specifications

Nitroethane, % by wt	35-40
1-Nitropropane, % by wt	60-65
Total nitroparaffin content % by wt (min.)	99.0
Water, % by wt (max.)	0.15
Color, APHA (max.)	20

Azeotropes of NiPar 640 Components
(Nitroethane and 1-Nitropropane)

		Azeotrope with Nitroethane		Azeotrope with 1-Nitropropane	
Component "A"	*Boiling Point, °C*	*Weight % Component "A"*	*Boiling Point, °C*	*Weight % Component "A"*	*Boiling Point, °C*
Water	100.0	28.5	87.2	36.5	91.63
Ethyl Alcohol	78.3	87.4	78.0	—	—
n-Propyl alcohol	97.2	68.2	94.5	91.2	96.95
Isopropyl alcohol	82.4	89.4	81.8	—	—
n-Butyl alcohol	117.8	45	107.7	67.8	115.3
sec-Butyl alcohol	99.5	72.4	97.2	95.9	99.4
Isobutyl alcohol	108.0	60	102.5	84.8	105.28
t-Butyl alcohol	82.4	95.5	82.2	—	—
Amyl alcohol	138.2	17	137.8	—	—
Isoamyl alcohol	131.9	22	112.0	—	—
Ethylene glycol monoethyl ether	135.1	—	—	36.1	128.3
n-Heptane	98.4	72	89.2	85.8	94.6
n-Nonane	150.8	—	—	36.4	126.2
Toluene	110.8	75	106.2	—	—
Ethylbenzene	136.2	—	—	41.0	127.5
o-Xylene	143.6	—	—	15.0	130.9
Ethyl butyrate	121.5	27	113.7	—	—
Ethyl isobutyrate	110.1	73	108.5	—	—
Isobutyl acetate	117.4	40	112.5	—	—
Ethylene glycol monomethyl ether	124.5	—	—	58.7	121.4

It is desirable that the optimum quantity of NiPar 640 be used for each particular system. This optimum will vary from system to system, but normally it will fall in the range of 8% to 25% of the solvent blend.

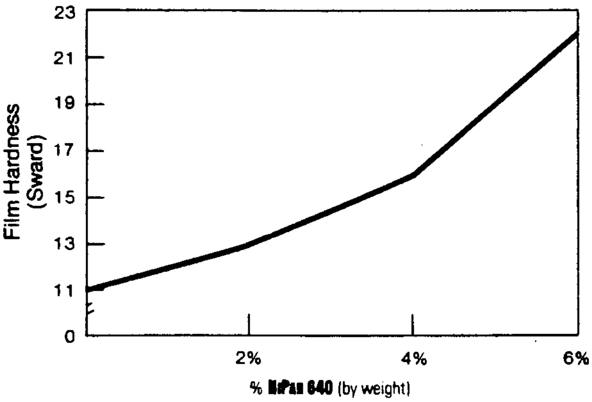
	Resistivity, megohm	*Relative Evaporation Rate**
Dimethylformamide	0.02	17
Ektasolve EM⁺	0.02	50
NiPar 640	0.03	100
Ektasolve EE⁺	0.04	38
Ektasolve EB⁺	0.05	10
Isopropyl alcohol, 99%	0.07	258
Isophorone	0.07	4
Methyl ethyl ketone	0.07	568
n-Butyl alcohol	0.08	48
Methyl isobutyl ketone	0.13	186
Isobutyl alcohol	0.15	90
Cyclohexanone	0.20	23

**n*-Butyl acetate = 100 ⁺Trademark of Eastman Kodak Company

(continued)

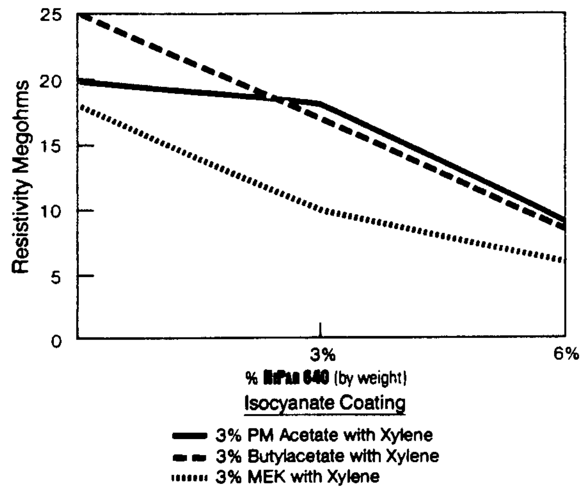
Table 4.7: (continued)

Improved Film Integrity



This significant improvement in cure time and film performance is best achieved when 3–6% (by weight) of the total solvent blend is replaced with NiPar 640.

Isocyanate Coating Lower Resistivity



NiPar 640 will provide the benefits of superior wetting, improved film integrity and improved cure time while enhancing electrostatic spray performance through its contribution to optimum resistivity of the coating.

Specific Gravities of Nitromethane-Methanol Fuel Mixtures *(34)*

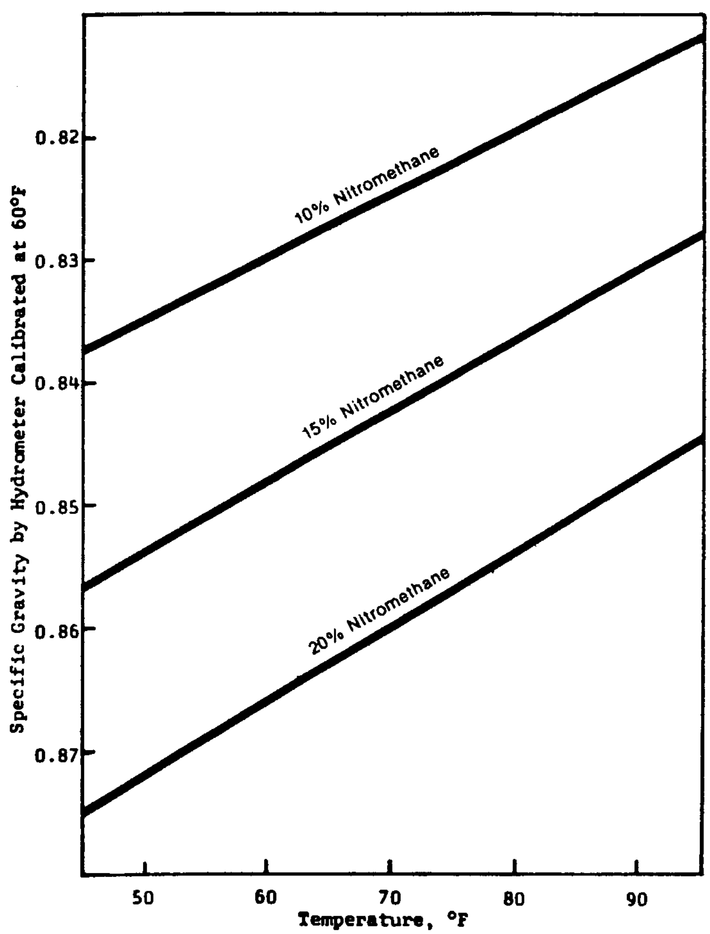
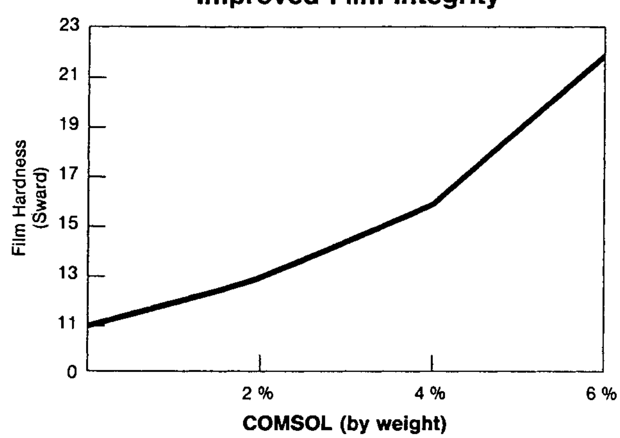


Table 4.8: COMSOL 101-X *(34)*

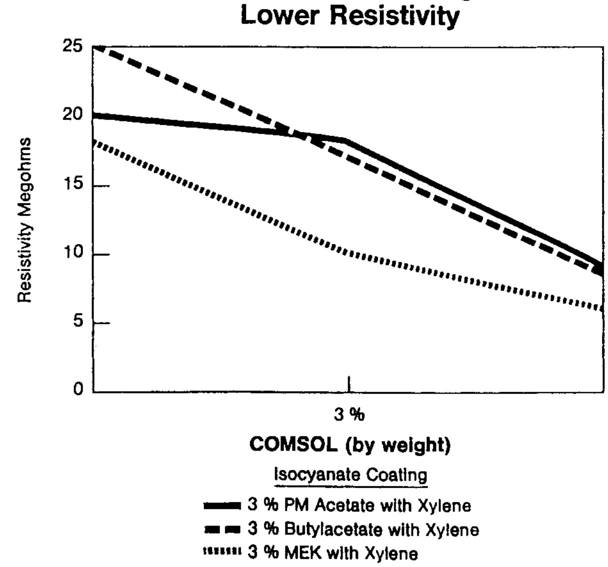
Typical Properties of COMSOL 101-X

Distillation range at 1013 hPa (90 % min.), °C	112-116
Freezing point, °C	−89.5
Vapour density (air = 1)	2.58
Specific gravity at 25/25 °C	1.045
Change of density with temperature, 0-50 °C, g/(ml x °C)	0.0012
Flash point, Tag closed cup, °C	31
Lower limit of flammability, % by vol. (at 30 °C)	3.4
Ignition temperature, °C	414
Evaporation rate, by vol. (n-butyl acetate = 100)	121
Evaporation number (diethyl ether = 1)	11
Solubility parameter, δ	11
Hydrogen bonding parameter, γ	2.5
Solubility in water at 20 °C, % by wt.	4.6

Improved Film Integrity



Isocyanate Coating Lower Resistivity

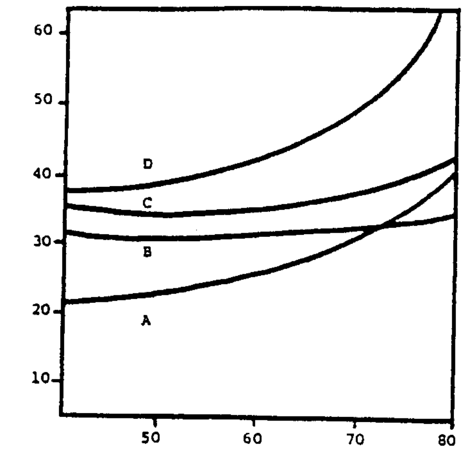


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Table 4.8: (continued)

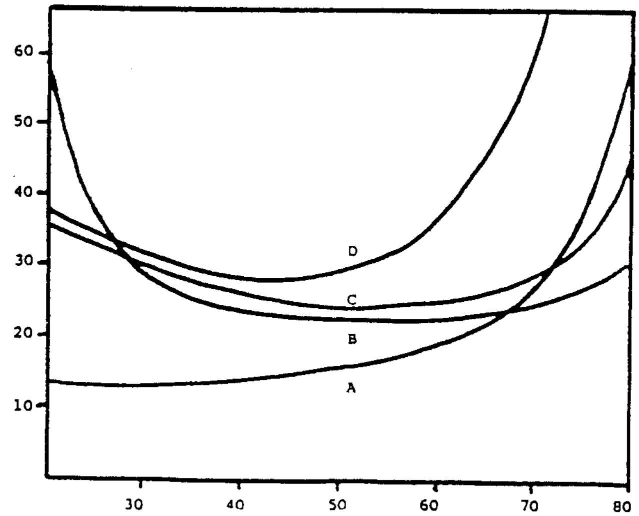
VISCOSITY OF VINYL RESIN SOLUTIONS

VISCOSITY; CENTIPOISE



15 g of Bakelite VYHH (D) in 100 ml solvent

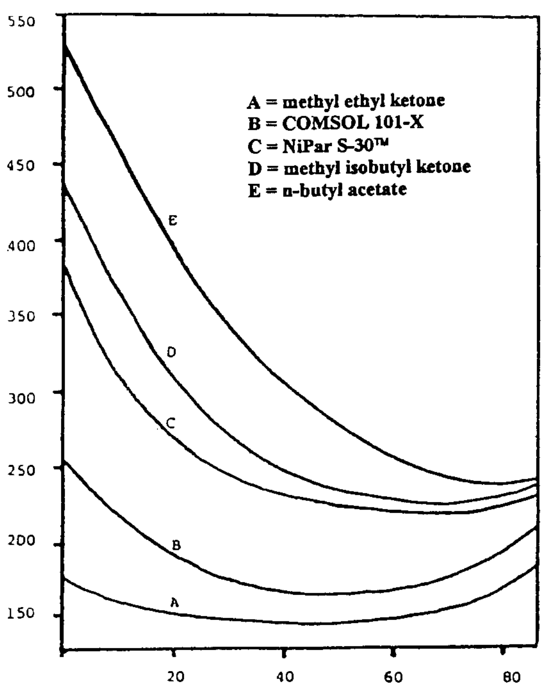
A = methyl ethyl ketone
B = COMSOL 101-X
C = NiPar S-20™
D = methyl isobutyl ketone



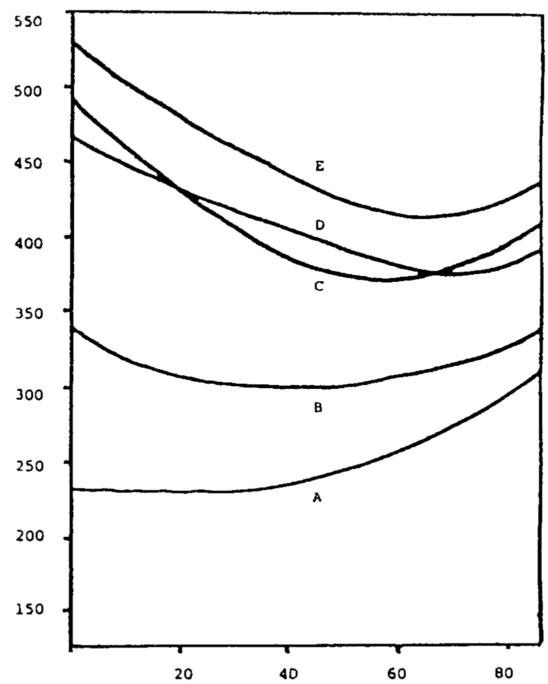
8 g of Bakelite VYNS-3 (D) in 100 ml solvent

TOLUENE; PERCENT BY VOLUME

VISCOSITY OF ACRYLIC RESIN SOLUTIONS



50 g Acryloid B-66 in 100 ml solvent



50 g Acryloid B-72 (A) in 100 ml solvent

TOLUENE; PERCENT BY VOLUME

Table 4.9: COMSOL 280 *(34)*

SPECIFICATIONS

Nitromethane, % wt.	75 - 85
1-Nitropropane, % wt.	15 - 25
2-Nitropropane, % wt. (max.)	0.1
Total nitroparaffins, % wt. (min.)	99
Water, % wt. (max.)	0.2
Colour, APHA (max.)	80

AZEOTROPES OF COMSOL 280 COMPONENTS

		Azeoptrope with Nitroethane		Azeotrope with 1-Nitropropane	
COMPONENT „A“	**B. P. (°C)**	**Wt. % Comp. „A“**	**B. P. (°C)**	**Wt. % Comp. „A“**	**B. P. (°C)**
Water	100.0	28.5	87.2	36.5	91.63
Ethyl alcohol	78.3	87.4	78.0	-	-
n-Propyl alcohol	97.2	68.2	94.5	91.2	96.95
Isoproyl alcohol	82.4	89.4	81.8	-	-
n-Butyl alcohol	117.8	45.0	107.7	67.8	115.30
sec-Butyl alcohol	99.5	72.4	97.2	95.9	99.40
Isobutyl alcohol	108.0	60.0	102.5	84.8	105.28
t-.Butyl alcohol	82.4	95.5	82.2	-	-
Amyl alcohol	138.2	< 17.0	< 37.8	-	-
Isoamyl alcohol	131.9	22.0	112.0	-	-
Ethylene glycol monoethyl ether	135.1	-	-	26.1	128.30
n-Heptane	98.4	72.0	89.2	85.8	94.60
n-Nonane	150.8	-	-	36.4	126.20
Toluene	110.8	75.0	106.2	-	-
Ethylbenzene	136.2	-	-	41.0	127.50
o-Xylene	143.6	-	-	15.0	130.90
Ethyl butyrate	121.5	< 27.0	113.7	-	-
Etyl isobutyrate	110.1	73.0	108.5	-	-
Isobutyl acetate	117.4	40.0	112.5	-	-
Ethylene glycol monomethyl ether	124.5	-	-	58.7	121.40

B.P. = Boiling Point

Table 4.10: COMSOL 820 *(34)*

PRODUCT SPECIFICATIONS

Total Nitroparaffins, % wt.	99.0 min.
Specific gravity, 25/25 °C	1.001 - 1.009
Water, % wt.	0.2 max.
Colour, APHA	80 max.

TOXICITY DATA

Skin irritation, Draize test :	non-irritating
Eye irritation, Draize test :	non-irritating
Mutagenicity :	due to the composition of the product no mutagenic effects must be expected.
Sensitization, LANDSTEINER & JACOBS (guinea pig):	non-sensitizing

Lower limits of flammability of some solvents (% by volume in air)

Methyl isobutyl ketone	0.9
Xylene	1.0
Toluene	1.27
n-Butyl acetate	1.7
Methyl ethyl ketone	1.7
Acetone	2.15
Ethylene glycol monoethyl ether	2.6

Flash point, °C (TCC)

Acetone	-19
Ethyl acetate	- 4
Methyl ethyl ketone	-14
Toluene	6
Methyl isobutyl ketone	14
Isobutyl acetate	18
Xylene	25
COMSOL 820	30.5
Cyclohexanone	44

Organic Sulfur Compounds

Table 5.1: Carbon Disulfide *(2)*

Chemical Names: Carbon Disulfide, Carbon Bisulfide
Common Names: Carbon Disulfide, Carbon Bisulfide
Formula: CS_2

PROPERTIES

Grades: Commercial or Technical, and USP
Important Physical and Chemical Properties

Physical State: Liquid.
Color: Clear, colorless liquid.
Odor: Almost odorless when pure; the commercial grade has a strong disagreeable odor, due to presence of sulfur compounds.
Specific Gravity at 20° C/4° C (68° F/39° F) (Water = 1): 1.263
Vapor Density (Air = 1): 2.63
Boiling Point (760 mm): 46.3° C (115° F)
Melting Point: −108.6° C (−163° F)
Flash Point (closed cup): −30° C (−22° F)
Explosive Limits (per cent by volume in air): 1 to 50
Ignition Temperature: 100° C (212° F)
Corrosive: Commercial grade slightly corrosive to some metals due to impurities.
Dangerously Reactive: No. However, it has an extremely low ignition temperature.
Hygroscopic: No.
Light Sensitive: Turns yellow when exposed to sunlight.

Vapor Pressure of Carbon Disulfide

Temperature		Vapor Pressure mm Mercury
°C	°F	
−78.2	−109	0.68
−42.6	−45	11.81
−25.35	−14	34.3
−21.5	−7	42.7
0	+32	127.0
11.54	53	211.3
19.7	67	294.3
46.3	115	760.0

Table 5.2: Typical DMSO Properties *(36)*

Auto ignition temperature in air	300-302°C (572-575°F)
Boiling point (1 atmosphere)	189°C (372°F)
Coefficient of expansion	0.00088/°C
Conductivity (Electrical)	
20°C	3×10^{-8} (ohm^{-1} cm^{-1})
80°C	7×10^{-8} (ohm^{-1} cm^{-1})
Critical heat flux	1.3×10^{5} Btu/hr x ft^{-2}
	(4.10×10^{5} J/s/m^2)
Critical molar volume	$2.38 \times 10^{-4} m^3$
Critical Pressure	56.3 atm. abs.
Critical temperature	447°C (837°F)
Density, at 25°C (see Figure 3)	1.0955 g/cm^3
Dielectric constant, 1MHz	
@ 20°C	48.9
@ 40°C	45.5
Diffusion coefficient	9.0×10^{4} cm^2/sec.
Dipole moment, D	4.3
Evaporation rate index @ 25°C	
Relative to n-butyl acetate	0.026
Relative to diethylether	0.0005
Flammability limits in air	
lower (100°C)	3-3.5% by volume
upper	42-63% by volume
Flash point (open cup)	95°C (203°F)
Flash point (closed cup)	89°C (192°F)
Freezing point	18.55°C (65.4°F)
Heat capacity (liq.), 25°C	0.47 cal/g/°C)
Heat capacity (ideal gas)	$Cp(T°K) = 6.94 + 5.6 \times 10^{-2} T$
	$-0.227 \times 10^{-4} T^2$
Heat of combustion	6054 cal/g
Heat of fusion	41.3 cal/g
Heat of solution in water at 25°C	–54 cal/g@∞ dilution
Heat of vaporization at 70°C	11.3 kcal/mol (260 Btu/lb)
Henry's constant @ 21°C	991000
Molar freezing point constant	4.07°C/mol
Molar volume	71.2 cm^3/gm
Molecular weight	78.13
pKa	35.1
pK BH+	–2.7
Refactive index N_D@25°C	1.4768
Solubility parameters	
Hansen's	
Dispersion	9.0 $(cal/cm^3)^{1/2}$
Polar	8.0 $(cal/cm^3)^{1/2}$
Hydrogen bonding	5.0 $(cal/cm^3)^{1/2}$
Hildebrand's	13.0 $(cal/cm^3)^{1/2}$
Specific heat at 29.5°C	0.47 ± 0.015 cal/g/°C
Surface tension at 20°C	43.53 dynes/cm
Vapor pressure at 25°C (see Figure 2)	0.600 mm Hg
Viscosity, cP, at 25°C (See Figure 4)	2.0
Log octanol-water partition coefficient	–1.35

Table 5.3: Vapor Pressure vs. Temperature for DMSO *(36)*

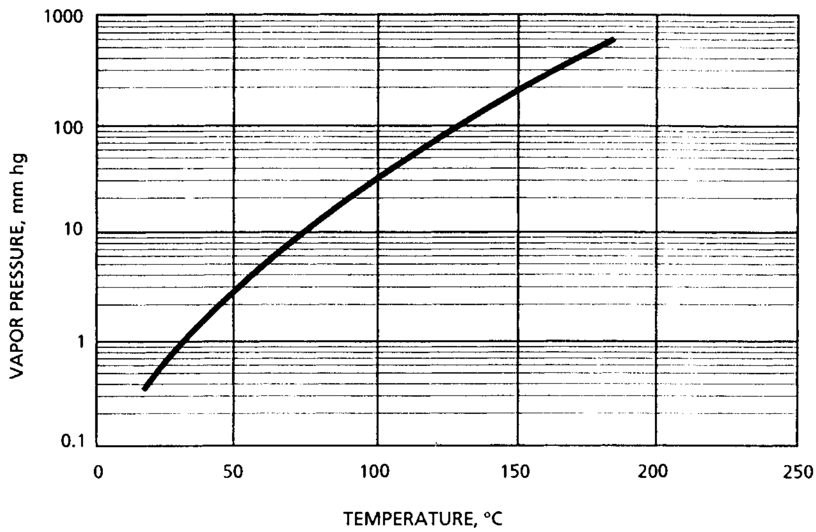


Table 5.4: Specific Gravity of DMSO as a Function of Temperature *(36)*

Temperature (°C)	Specific gravity (g/cm³)
15.6	1.1047
21	1.0993
25	1.0955
30	1.0904
40	1.0803
50	1.0702
75	1.0454
100	1.0200
125	0.9946
150	0.974

Table 5.5: DMSO Viscosity as a Function of Temperature *(36)*

Temperature (°C)	Viscosity (cP)
25	1.991
30	1.808
40	1.511
50	1.286
75	0.916
100	0.691
125	0.546

Table 5.6: Comparative Hygroscopicities of DMSO at Various Relative Humidities at 22°C *(36)*

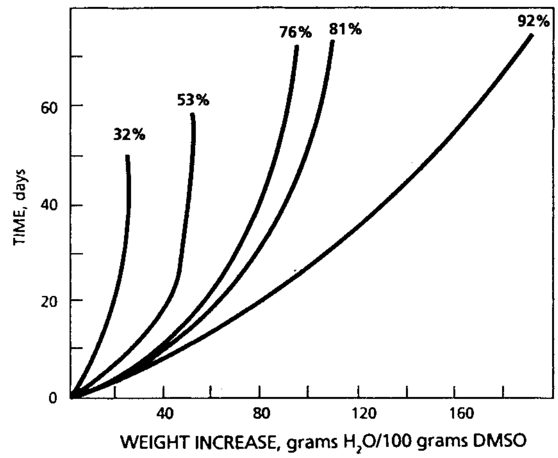


Table 5.7: Initial Sorption Rates of DMSO at Various Relative Humidities at 22°C *(36)*

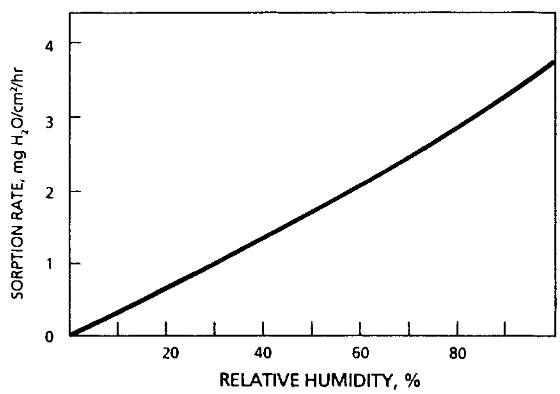


Table 5.8: Freezing Temperatures for DMSO—Solvent Binary System *(36)*

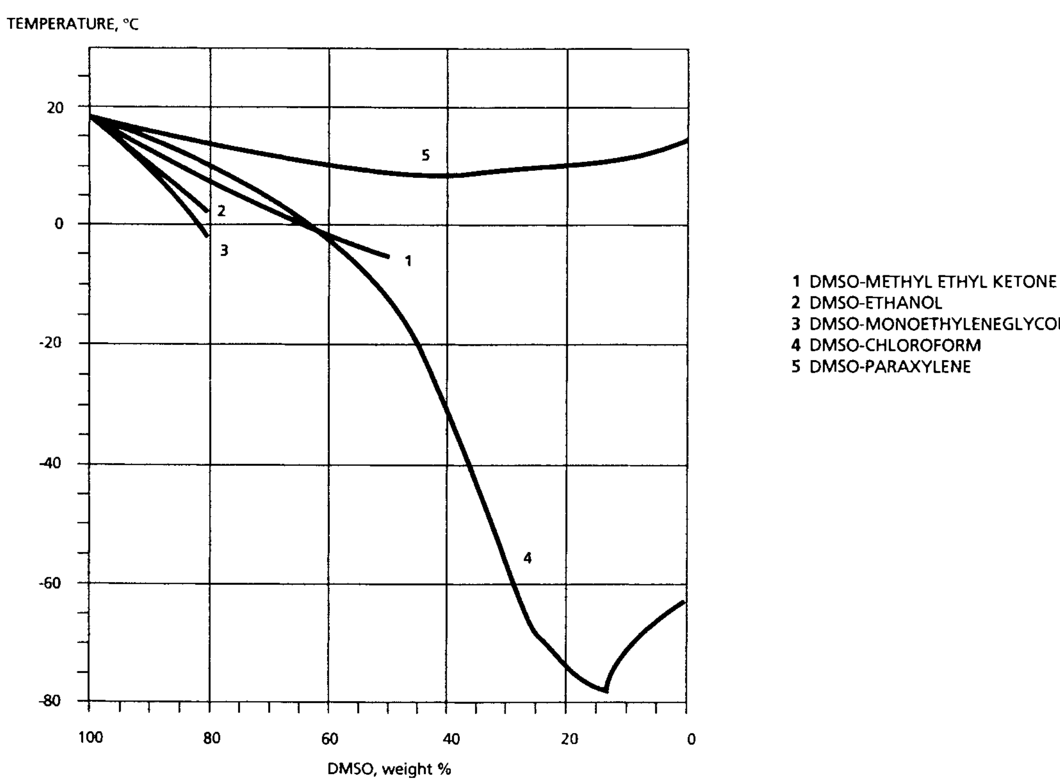


Table 5.9: Freezing Point for DMSO—Water Solutions *(36)*

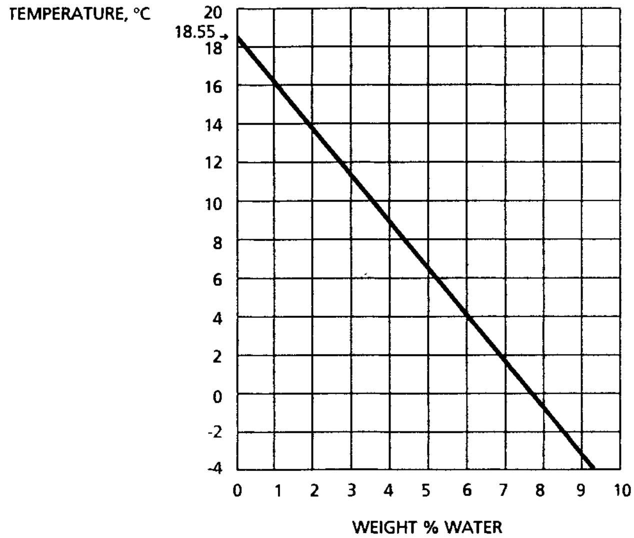


Table 5.10: Freezing Point Curves for DMSO—Water Solutions *(36)*

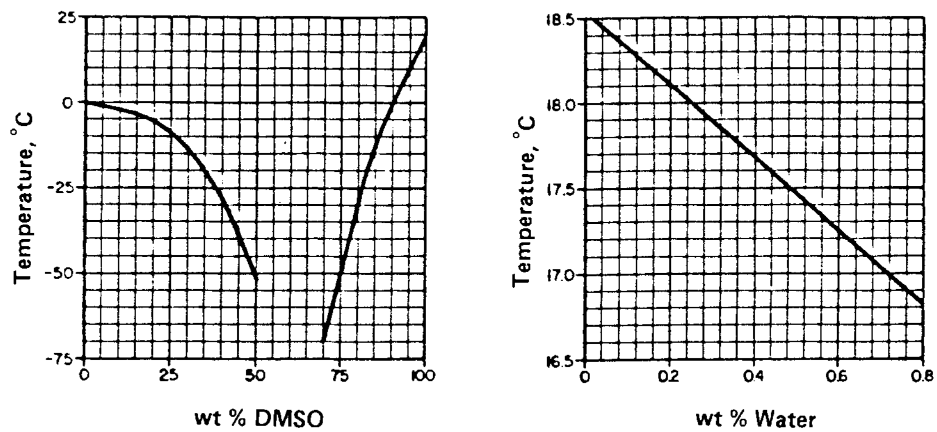


Table 5.11: Heat of Mixing of DMSO—H_2O System at 22°C *(36)*

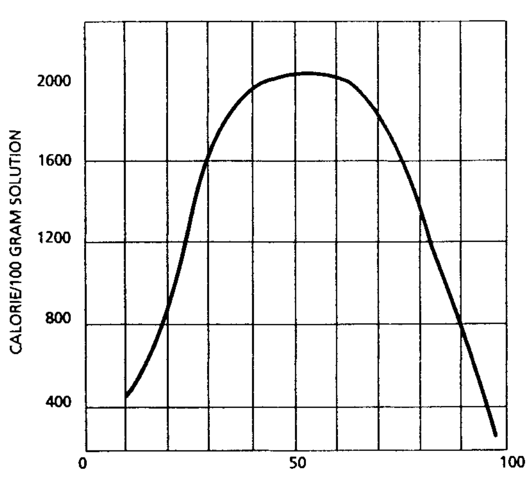


Table 5.12: Specific Gravity of DMSO—Water Solutions *(35)*

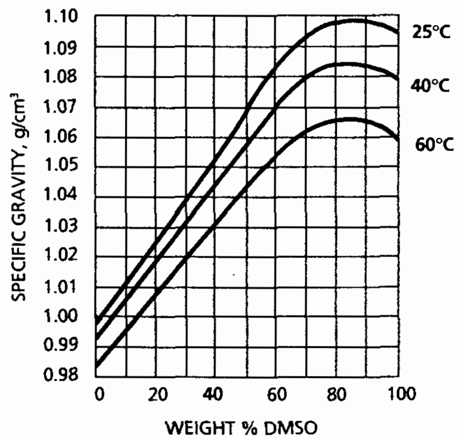


Table 5.13: Viscosity of DMSO—Water Solutions *(36)*

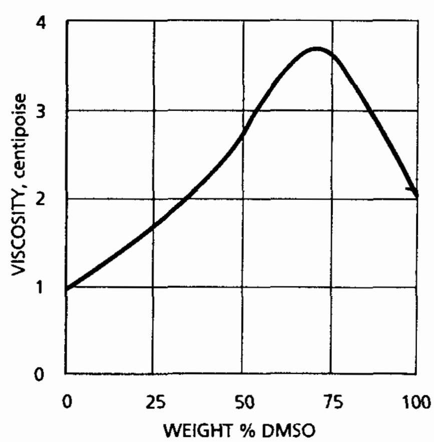


Table 5.14: Results of Reflux of DMSO for 24 Hours with Various Compounds *(35)*

COMPOUND (100g) IN 300g DMSO	REFLUX TEMP., °C	DMSO RECOVERED % OF ORIGINAL	% DECOMPOSITION PRODUCTS, DMS[(a)]	DMDS[(b)]	BMTM[(c)]	HCHO	MM[(d)]
NaOH	185-140[(e)]	93.7	63	31	—	—	—
Na_2CO_3	190	96.3	—	14	—	—	—
NaCl	190	98.7	—	15	—	—	—
NaCN	148-164[(f)]	100.0	—	—	—	—	—
NaOAc	182-187	97.0	22	33	8	20	—
Na_2SO_4	181-148[(g)]	85.4	66	—	—	—	11
DMSO ONLY	189	98.0	15	30	30	—	—

(a) Dimethyl sulfide
(b) Dimethyl disulfide
(c) Bis(methylthio) methane
(d) Methyl mercaptan
(e) Reflux temperature decreased from 185°C to 140°C over the first 16 hours.
(f) Reflux temperature was 148°C for 20 hours; increased to 164°C during the last 4 hours.
(g) Reflux temperature decreased gradually from 181°C to 148°C.

Table 5.15: Thermal Stability of DMSO *(36)*

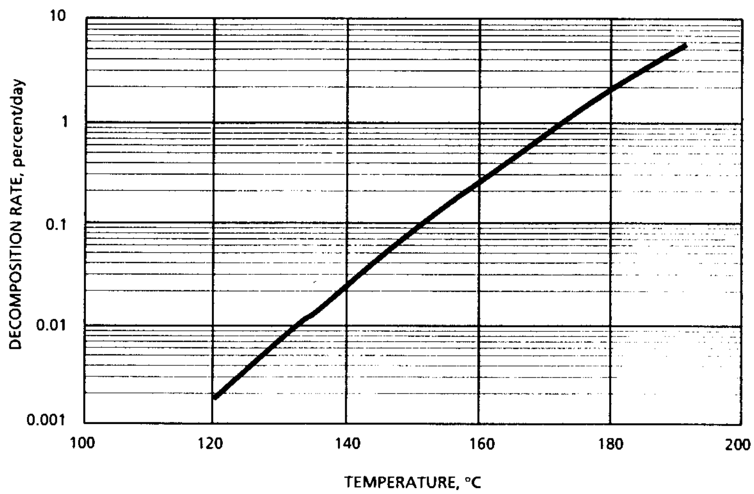


Table 5.16: Refluxing of DMSO and Mixtures for Shorter Periods *(36)*

COMPOSITION OF SAMPLE PARTS	REFLUX TEMP,°C	TIME HR.	ORGANIC PRODUCT COMPOSITION % DMSO	DMS	DMDS	BMTM
10 DMSO:1 H_2O	152	5	100	0	0	0
		15	99.7	0.15	0	0.15
60 DMSO: 5H_2O:1 NaOH	155	5	99.8	0.1	0.1	0
		8	99.3	0.6	0.1	0
60 DMSO:12 H_2O: 1 $NaHCO_3$	131	6	99.9	0.1	0	0
		12	99.8	0.2	0	0
DMSO ONLY	191	5	99.8	0.1	0.1	0
		9	99.1	0.2	0.2	0.5
		16	99.0	0.2	0.2	0.6

Table 5.17: Effect of Heating DMSO with Concentrated Acids *(36)*

(200g DMSO WITH 20g OF CONCENTRATED ACID)

ACID	CONC.	TEMP., °C	TIME, MIN.	DMSO LEFT %	% OF DECOMPOSITION PRO DMS[a]	DMDS[b]	HCHO
H_2SO_4	36N	100	15	99	100		
			30	99	100		
			120	98	100		
H_2SO_4	36N	125	15	86	7	93	
			150	86	7	93	
			210	80	10	90	
H_3PO_4	85%	100	15	92	25	75	
			30	89	45	55	
			45	89	45	55	
			60	87	46	54	
			120	87	46	54	
			150	86	50	50	SOME
H_3PO_4	85%	125	15	84	25	75	
			60	82	33	67	
			150	82	33	67	
HCl	12N	95	15	99	100		
			30	99	100		
			60	99	100		
			120	98	100		
HCl	12N	115	15	93	100		
			30	92	100		
			45	87	100		
			60	87	100		
			120	87	100		SOME

(a) Dimethyl Sulfide
(b) Dimethyl Disulfide

Table 5.18: Solubility of Organic Materials in DMSO *(36)*

Material	Solubility Grams/100 cc DMSO 20-30°C	90-100°C
Acetic acid	Miscible	-
Acetone	Miscible	-
Acrawax	< 1	> 1
Acrawax B	Insol.	4
Aniline	Miscible	-
Anthracene	2	-
Beeswax	-	< 1
Benzene	Miscible	-
Benzidine	Soluble	-
Benzidine methane sulfonate	Insol.	-
Bromoethane	Miscible	
Butenes	2.1	
n-Butyl acetate	Miscible	
Butly carbitol	Miscible	
Calcium methyl sulfonate	Soluble	
Camphor	Soluble	Soluble
Candelilla wax		< 1
Carbon	Insol.	
Carbon disulfide	90	
Carbon tetrachloride	Miscible	
Carbowax 600	Miscible	
Carbowax 6000	Insol.	8
Carnauba wax		< 1
Castor oil	Miscible	
Ceresin wax		< 1
Chloroform	Miscible	
Chlorosulfonic acid	Reacts	
Citric acid	> 70	
Coconut oil	0.3	1.3 Misc.-160°C
Cresylic acid	Miscible	
Cumene	Miscible	
Cyclohexane	4.67	
Cyclohexene	Miscible	
Cyclohexylamine	Miscible	
Decalin	4.5	
n-Decane	0.7	
Di-n-butylamine	11	
o-Dichlorobenzene	Miscible	
p-Dichlorobenzene	Very Soluble	
SDichlorodiphenyl-trichloroethane	4	100
Dicyandiamide	40	
Dicyclohexylamine	4.5	
Diethanolamine	Miscible	
Diethylamine	Miscible	
Diethyl ether	Miscible	
bis-(2-ethylhexyl)amine	0.7	
Diethyl sulfide	Miscible	
Di-isobutyl carbinol	Miscible	
Di-isobutylene	3.3 (0.6% DMSO soluble in di-isobutylene)	
Disopropyl ether	11	
Dimethyl ether	4.4	
Dimethyl formamide	Miscible	
Dimethyl sulfide	Miscible	
Dimethyl sulfone	33.9	Miscible
Dioxane	Miscible	
Diphenyl	Very soluble	
Dipentene	10	
Dodecanol	>100	
n-Dodecane	0.38	
Dodecylbenzene (Neolene 400)	3. 5	
Dyes		
Burnt Sugar	Soluble	
FD&C Blue	Soluble	
Pistachio Green B	Soluble	
1-Eicosanol	Insol.	
Ethyl benzoate	Miscible	
Ethyl alcohol	Miscible	
Ethyl bromide	Miscible	Reacts
Ethyl ether	Miscible	
Ethylene dichloride	Miscible	
Formalin (37%)	Miscible	
Formamide	Miscible	
Formic acid	Miscible	
Glucose	54	
Glycerine	Miscible	
Glycine	< 0.05	0.1
Hexane	2.9	
4-Hydroxy benzoic acid	24	
Hy-Wax 120		< 1
Imidazole	80	
Isophthalic acid	68	76
Isoprene	Miscible	
Kerosene	0.5	
Lanolin, hydrated (Lanette 0)		11 (gets cold)
Lauryl amide (Armid 12)	10	> 20
Linear alcohols	Miscible	
Lorol 5	Miscible	
Lubricating oil	0.4	
Methionine	0.1	0.3
Methyl borate	Miscible	
Methyl caprate		Miscible
Methyl iodide	Miscible	Reacts
Methyl isobutyl ketone	Miscible	
Methyl laurate	7	Miscible
Methyl mercaptan	40 (Reacts)	
N-methyl morpholine	Miscible	
Methyl palmitate	Immiscible	Misc. 130-180°C
Methyl salicylate	Miscible	
Methyl sulfonic acid	Miscible	
Methylene chloride	Miscible	
Microcrystalline wax		< 1
Morpholine	Miscible	
Naphthalene	40	Miscible
Neoprene	Insol.	Insol.
Nitrobenzene	Miscible	
Oleic acid	Miscible	
Ouricuri wax		1
Oxalic acid	38	
Palmitic acid	100	
Paraffin	Insoluble	
Paraformaldehyde	Insoluble	Slightly soluble
Paradichlorobenzene	56	
Pentaerythritol	5-10	30
n-Pentane	0.35	
Pentene 1&2	7.1	
Perchloric acid	Reacts violently	
Petroleum ether	3 (DMSO soluble 0.3-0.5% in petroleum ether)	

(continued)

Table 5.18: (continued)

Material	Solubility Grams/100 cc DMSO 20-30°C	90-100°C	Material	Solubility Grams/100 cc DMSO 20-30°C	90-100°C
Phenol	>100		Tallow	Insol.	1.9
Phosphoric acid	Miscible		Tallow amide, hydrogenated (Armour Armide HT)	Insol.	> 40
Phosphorus trichloride	Reacts vigorously		Terephthalic acid	26	33
Phthalic acid	90		Tetrahydrophthalic anhydride	50	
Picric acid	Soluble		Tetralin	Miscible	
Pyridine	Miscible		Tetrapropylene	1	
Pyrogallol	50		Thiourea	40	85
Rosin	> 100		Toluene	Miscible	
Rosin soap (Hercules Dresinate X)	Slightly soluble	0.9	Toluene di-isocyanate	Miscible	
Sevin	50		Tributylamine	0.9	
Silicon tetrachloride	Reacts vigorously		Tricresyl phosphate	Miscible	
Sorbitan sesquioleate	2.5		Triethanolamine laurylsulfate	Soluble	
Sorbitan trioleate		Miscible	Triethanolamine	Miscible	
Sorbitol	60	> 180	Triethylamine	10	
Soybean oil	0.6		Trinitrotoluene	Soluble	
Starch, soluble	> 2		Turpentine	10	
Stearic acid	2	Miscible	Urea	40	110
Succinic acid	30		Xylene	Miscible	
Sugar (sucrose)	30	100			
Sulfamic acid	40				
Sulfuric acid	Miscible				

Table 5.19: Solubility of Resins and Polymers in DMSO *(36)*

Material	Solubility, Grams/100cc DMSO 20-30°C	90-100°C	Comments
Aminoplasts			
Melamine Formol	Soluble		
Urea formol	Soluble		
Polyacrylics			
Orlon (DuPont)	-	20	Viscous soln.
Acrilan (Monsanto)	>25		
Verel (Eastman)	> 5		25 at 130°C with some decomposition
Creslan (Am. Cyanamid)	5		25 at 130°C
Polyamides			
Nylon 6	-	Insol.	40 at 130°C
Nylon 6/6	-	Insol.	25 at 150°C
Nylon 6/10	-	Insol.	40 at 150°C
Nylon 11 Rilsan(Elf Ato)	-	Insol.	-
Nylon 12 Oryasol(Elf Ato)	-	Insol.	Soluble @ 140°C
Polyimides			
Bismaleimide copolymers			
Kermid 353 (Rhone-Poulenc)	Swells		
Kermid 711 (Rhone-Poulenc)	Soluble		
Polyamino bis maleimide			
Kermid 601(Rhone poulenc) I	-	Insol.	
Polyamideimide			
Torlon 4203L (Amoco)		Insol.	
Polyetherimide			
Ultem 100 (G.E.)	Swells		
Cellulose			
Cellulose triacetate	10	20	
Viscose rayon	-	<1	
Cellophane	-	Insol.	
Carboxymethyl cellulose	-	Insol.	
Nitrocellulose	-	10	

(continued)

Table 5.19: (continued)

Material	Solubility, Grams/100cc DMSO 20-30°C	90-100°C	Comments
Cellulose			
Cellulose triacetate	10	20	
Viscose rayon	-	<1	
Cellophane	-	Insol.	
Carboxymethyl cellulose	-	Insol.	
Nitrocellulose	-	10	
Chlorinated Resins			
Butaclor MC30 (Distugil)	Swells		
CM3630 (Bayer)	Swells		
Hypalon DH70 (DuPont)	Swells		
Epoxies			
Epikote 1004 (Shell)	Soluble		
Epon 1001 (Shell)	50		
Epon 1004 (Shell)	50		
Epon 1007 (Shell)	50		
Fluorinated Resins			
Polyvinylidene floride			
Foraflon (Atochem)	Swells		
Elastomers			
Viton DF801 (DuPont)	Swells		
Viton DF809 (DuPont)	Swells		
Kalrez 4079 (DuPont)	Insol.		
Teflon (DuPont)	Insol.	Insol.	
Methacrylates			
Lucite 41, 4S (DuPont)	-	<1	
Plexiglas (Rohm & Haas)	-	<1	
Phenoplasts			
Modified Novalac			
R7522 (Ceca)	Soluble		
R7550 (Ceca)	Soluble		
Norsophen Resin PH 13 (CDF Chime)	Soluble		
Polycarbonates			
Lexan (General Electric)	-	>5	
Polyesters			
Dacron (DuPont)	-	>1	Dissolves at 160°C; ppts at 130°C
CX 1037 (Goodyear)	-	7	
Atlac (ICI-America)	-	50	
Poly(ethylene terephthalate)	-	-	-
Poly(butylene terephthalate)	-	-	-
Hytrel (DuPont)	-	-	-
Silicones			
Dow Corning 803 soln.	Miscible	-	
Dow Corning 805 soln.	Miscible	-	
Dow Corning "Sylkyd 50"	Miscible	-	
Dow Corning Z6018 (flake)	70	-	
Sulfur Resins			
Polyphenylene sulfide			
Ryton V107 (Philips)	Swells		
Polyethersulfone			
Victrex 660P (ICI)	Soluble		
Ultrason E3000 (BASF)	Soluble		
Udel (Amoco)	Soluble		
Urethanes			
Vithane (Goodyear)	-	100	
Vinyle-Polymers & Co-polymers			
Butvar B-76 (Monsanto)	-	20	Very viscous
Formvar 7/70 E Monsanto)	-	42	Very viscous
Elvanol 51-05 (DuPont)	-	90	Viscous
Elvanol 52-22 (DuPont)	-	15	Viscous
Elvanol 71-24 (DuPont)	-	30	Viscous

(continued)

Table 5.19: (continued)

Material	Solubility, Grams/100cc DMSO 20-30°C	90-100°C	Comments
Polyvinyl pyrrolidone (GAF)	30	>100	
Geon 101 (PVC Goodrich)	-	10	
Vinylite WHH (Union Carbide)	2	30	
Teslar (DuPont)	-	-	Partially sol. at 160-170°C
Vinylidenes			
Darvan (Goodrich)	5	-	Soln. cloudy and viscous
Saran film (Dow)	-	30	
Geon 200 x 20 (Goodrich)	-	20	
DNA (Goodrich)	>5	-	25 at 130°C
Other Resinous Materials			
Melmac 405 (Am. Cyanamid)	70	-	
Neoprene	Insol.	Insol	
Polyetherether ketone (PEEK) (ICI)	Insol.		
Polyethylene	Insol.	Insol.	
Polypropylene	Insol.	Insol.	
Polystyrene	-	-	Sol. at 150°C; ppts at 130°C
Rosin (Hercules)	>100	-	
Penton (chlorinated polyether)(Hercules)	-	5	
Vinsol (Hercules)	50	>100	

Table 5.20: Solubility of Inorganic Materials in DMSO *(36)*

	Solubility, Grams/100cc DMSO 25°C	90-100°C		Solubility, Grams/100cc DMSO 25°C	90-100°C
Aluminum sulfate (18H_2O)	Insol.	5	Magnesium nitrate (6H_2O)	40	
Aluminum chloride	Reacts		Manganous chloride (4H_2O)	20	
Ammonium borate (3H_2O)	10		Mercuric acetate	100	
Ammonium carbonate(H_2O)	1		Mercuric bromide	90	
Ammonium chloride	Insol.	10	Mercuric iodide	100	
Ammonium chromate	1		Mercuric sulfate	<0.01	
Ammonium dichromate[c]	50		Molybdenum bromide	1	Reacts
Ammonium nitrate	80		Nickel chloride(6H_2O)	60	
Ammonium thiocyanate	30		Nickel nitrate (6H_2O)	60	
Barium nitrate	1		Potassium bromide	6.5	
Beryllium nitrate(4H_2O)	10		Potassium chloride	0.2	
Bismuth trichloride	1		Potassium cyanide	1	2
Boric acid	45[a]		Potassium hydroxide	0.013	
Bromine	Reacts		Potassium iodide	20	20
Cadmium chloride	20[b]		Potassium nitrate	12	
Cadmium iodide	30		Potassium nitrite	2	
Calcium chloride	Insol.		Potassium perchlorate[c]	38	
Calcium dichromate(3H_2O)[c]	50		Potassium thiocyanate	20	50
Calcium nitrate(4H_2O)	30		Silver chloride	<0.01	
Ceric ammonium nitrate	1		Silver iodide	<0.01	
Cobaltous chloride (6H_2O)	30	Misc m.p.	Silver nitrate	130	180
		86°C	Sodium Sulfate	<0.01	
			Sodium azide	<1.0	1.6
Cupric acetate(H_2O)	Insol.	6	Sodium chloride	0.4	
Cupric bromide[b]	1	20	Sodium cyanide	1	10
		150°C	Sodium dichromate(2H_2O)[c]	12	
Cupric chloride(2H_2O)	Insol.	27	Sodium hydroxide	0.035	
Cupric sulfate(SH_2)	<0.01		Sodium iodide	30	
Cuprous iodide	1 at 30°C		Sodium nitrate	20	
Ferric ammonium sulfate			Sodium nitrite	20	
(12H_2O)	Insol.	Misc. m.p.	Sodium perchlorate[c]	24.2	
		40°C	Sodium thiocyanate	1	
Ferric chloride(6H_2O)	30	90	Stannic chloride	25	
Ferrous chloride(4H_2)	30	90	Stannous chloride(2H_2O)	40	
Gold chloride	5		Strontium bromide(6H_2O)	5	
Iodine	>100		Strontium chloride(2H_2O)	10	
Lead chloride[b]	10		Sulfur dichloride	Reacts violently	
Lead nitrate	20	60	Sulfur monochloride	Reacts violently	
Lithium bromide	31.4		Tungsten hexachloride	5	
Lithium chloride	10.2		Uranyl nitrate (6H_2O)	30	
Lithium dichromate(2H_2O)[c]	10		Vanadium chloride		1
Lithium iodide	41.1		Zinc acetate	>100	
Lithium nitrate	10		Zinc chloride	30[b]	
Lithium perchlorate[c]	31.5		Zinc nitrate(6H_2O)	55	
Magnesium chloride(6H_2O)	1.0		Zinc sulfate	<0.01	

a) @20.3°C b) possible reaction c) not recommended due to safety considerations

Table 5.21: Solubility of Gases in DMSO at Atmospheric Pressure and 20°C *(36)*

(FROM PURE GASES IN EACH CASE)

	Grams Gas/ 100 Grams Solution	Gas Volume/ Volume of DMSO
Acetylene	2.99	28.1
Ammonia	2.6	40.0
Butadiene	4.35	31.0
Butane		4.8
Butylenes (mixed)	2.05	
Carbon dioxide	.05	2.86
Carbon monoxide	<0.01	
Ethane	6.85×10^{-2}	0.56
Ethylene	.32	2.8
Ethylene oxide	60.0	306.0
Freon 12	1.8	3.7
Helium	1.46×10^{-4}	0.89×10^{-2}
Hydrogen	1.95×10^{-4}	2.39×10^{-2}
Hydrogen sulfide	0.5 (reacts)	
Isobutylene	2.5-3.0	
Methane	7.92×10^{-3}	
Nitric oxide (NO)	0.00	
Nitrogen	2.99×10^{-3}	0.6
Nitrogen dioxide(NO_2,N_2O_4)	Miscible (possible reaction)	
Oxygen	6.44×10^{-3}	0.049
Ozone	Reacts	
Propane		1.8
Propyne		58.2
Sulfur dioxide	57.4 (reacts)	

Table 5.22: Solubility Parameters of Strong Solvents *(36)*

Solvent	δ_d	δ_p	δ_h	δ_t
DIMETHYL SULFOXIDE (DMSO)	9.0	8.0	5.0	13.0
8utyrolactone	9.3	8.1	3.6	12.8
Dimethylacetamide (DMAC)	8.2	5.6	5.0	11.1
Dimethylformamide (DMF)	8.5	6.7	5.5	12.1
N-Methyl-2-pyrrolidone (NMP)	8.8	6.0	3.5	11.2
Propylene Carbonate	9.8	8.8	2.0	13.3
Sulfolane	9.0	7.4	5.3	12.8

Table 5.23: DMSO as a Solvent Replacement *(36)*

Solvents to be Replaced				Replacement Mixture			
	δ_d	δ_p	δ_h	Weight %	δ_d	δ_p	δ_h
Acetone	7.6	5.1	3.4	65% DMSO 35% Aromatic 150	8.8	5.0	3.6
Butyl cellosolve	7.8	2.5	6.0	10% DMSO 30% Aromatic 150 60% Isopropyl alcohol	8.0	2.7	5.9
Butyrolactone	9.3	8.1	3.6	100% DMSO	9.0	8.0	5.0
Cellosolve	7.9	4.5	7.0	33% DMSO 67% Butyl alcohol	8.1	4.2	7.0
Cyclohexanone	8.7	3.1	2.5	40% DMSO 60% Aromatic 100	8.9	3.2	2.4
Dimethyl acetamide	8.2	5.6	5.0	67% DMSO 33% Amyl acetate	8.6	5.3	5.0
Dimethyl formamide	8.5	6.7	5.5	80% DMSO 20% 2-methyl butanol	8.6	6.6	5.4
Ethyl amyl ketone	8.0	2.5	2.1	30% DMSO 70% Aromatic 100	8.9	2.5	2.0
Ethylene glycol butyl ether acetate	8.1	2.8	6.7	20% DMSO 60% Butyl alcohol 20% Amyl acetate	8.0	3.3	6.6
Isophorone	8.1	4.0	3.6	50% DMSO 40% Aromatic 100 10% n-Butanol	8.9	4.1	3.5
Methyl ethyl Ketone	7.8	4.4	2.5	20% DMSO 80% MIBK	7.8	3.8	2.5

(continued)

Table 5.23: (continued)

Solvents to be Replaced				Replacement Mixture			
Methylene chloride	8.9	3.1	3.0	40% DMSO 60% Aromatic 150	8.7	3.1	2.7
Nitrobenzene	9.8	4.2	2.0	45% DMSO 55% Toluene	8.9	3.6	2.6
NMP	8.8	6.0	3.5	70% DMSO 30% Aromatic 100	8.9	5.4	3.6
Pentoxone (discontinued)	7.3	4.2	2.8	50% DMSO 50% Aromatic 100	8.9	3.9	2.8
Propylene carbonate	9.8	8.8	2.0	100% DMSO	9.0	8.0	5.0
Sulfolane	9.0	8.1	3.6	100% DMSO	9.0	8.0	5.0

Table 5.24: Hansen Solubility Parameters of Polymer Envelopes *(36)*

Polymer	δ_d	δ_p	δ_h	Radius
Polymethylmethacrylate Rohm & Haas	9.1	5.1	3.7	4.2
Epoxy - "Epicote" 1001 Shell Chemical	10.0	5.9	5.6	6.2
Polystyrene BASF	10.4	2.8	2.1	6.2
Polyvinyl acetate "Mowilith" 50 Farbwerke Hoechst	10.2	5.5	4.7	6.7
Nitrocellulose 1/2 sec. H 23 A. Hagedorn	7.5	7.2	4.3	5.6
Cellulose acetate "Cellidora" A. Bayer A.G.	9.1	6.2	5.4	3.7
Polyester "Desmophen" 850 A. Bayer A.G.	10.5	7.3	6.0	8.2
Polyvinyl chloride "Vipla"KR Montecatini	8.9	3.7	4.1	1.7

Table 5.25: Polymer Solvency of DMSO/Tetralin Mixtures *(36)*

Polymer		Solvency[1] Versus Mixture Composition						
	DMSO, % Tetralin, %	100 0	80 20	60 40	50 50	40 60	20 80	0 100
Polymethylmethacrylate Rohm & Haas		42	87	99	93	80	38	ns
Epoxy - "Epicote" 1001 Shell Chemical		77	85	81	-	60	32	ns
Polystyrene BASF		ns	35	70	-	87	91	84
Polyvinyl acetate "Mowilith" 50 Farbwerke Hoechst		73	86	89	84	77	57	28
Nitrocellulose 1/2 sec. H 23 A. Hagedorn		67	65	65	-	4	ns	ns
Cellulose acetate "Cellidora A. Bayer A.G.		74	89	61	-	0	ns	ns
Polyester "Desmophen" 850 A. Bayer A.G.		85	83	74	-	57	35	5
Polyvinyl chloride "Vipla" KR Montecatini		ns	ns	ns	68	ns	ns	ns

[1] Solvency = $100[1-(\Delta\delta / R)^2]$ See appendix, equation 5 for explanation.
If Solvency < 0, rating is "ns" indicating not soluble.

Table 5.26: Polymer Solvency of DMSO/MIKB Mixtures *(36)*

Polymer		Solvency[2] Versus Mixture Composition					
	DMSO, %	100	80	60	40	20	0
	MIBK, %	0	20	40	60	80	100
Polymethylmethacrylate Rohm & Haas		42	77	84	67	38	0
Epoxy - "Epicote" 1001 Shell Chemical		77	73	58	38	9	ns
Polystyrene BASF		ns	15	27	30	21	12
Polyvinyl acetate "Mowilith" 50 Farbwerke Hoechst		73	72	64	43	28	6
Nitrocellulose l/2 sec. H 23 A. Hagedorn		67	83	82	69	51	27
Cellulose acetate "Cellidora" A. Bayer A.G.		74	81	54	0	ns	ns
Polyester "Desmophen" 850 A. Bayer A.G.		85	74	58	39	16	ns
Polyvinyl chloride "Vipla" KR Montecatini		ns	ns	ns	ns	ns	ns

[1] MIBK- methyl isobutyl ketone

[2] Solvency = $100[1-(\Delta\delta / R)^2]$ See appendix, equation 5 for explanation.
If Solvency < 0, rating is "ns" indicating not soluble.

Table 5.27: Solvent Viscosities *(36)*

Solvent	Viscosity, cps @25°C
DIMETHYL SULFOXIDE (DMSO)	2.0
Dimethylformamide (DMF)	0.8
N-Methyl-2-pyrrolidone (NMP)	1.6
Butyrolactone	1.7
Cyclohexanone	2.1
Isophorone	2.5
Diacetone alcohol	3.0
Propylene Carbonate	4.0
Sulfolane	10.3 @ 30°C

Table 5.28: Solvent Evaporation Times *(36)*

Solvent	90% Evaporation Times, seconds
DIMETHYL SULFOXIDE (DMSO)	17,600
Cyclohexanone	1,570
Dimethylformamide (DMF)	2,280
Diacetone alcohol	3,840
N-Methyl-2-pyrrolidone (NMP)	15,400
Isophorone	20,000
Butyrolactone	23,700
Propylene carbonate	119,660
Sulfolane	>1,000,000

SULFOLANE

Table 5.29: Properties of Sulfolane *(4)*

Property	Typical Value	Specification	Test Method
Distillation, Range, °C, 760 mm			ASTM D 1078
5%	284.8	282 Min.	
50%	285.2		
95%	285.6	288 Max.	
Specific Gravity, 30/4°C	1.264		ASTM D 891
100/4°C	1.201		
Flash Point, °F	330		Literature Value
Freezing Point, °F	79		PPCo-6518-CH
Composition, wt. %			Gas Chromatography
Sulfolane (Water-free)	99.9	99.0 Min.	PPCo-6517-CG-1
Ash Content, wt. %	0.006	0.1 Max.	PPCo-7505-CF
Water Content, wt %	0.06	0.25 Max.	ASTM D 1744
SO_2 Stability, mg SO_2/250 ml/hr	4	20 Max.	PPCo-6533-CZ
Molecular Weight	120.17		Literature Value
Boiling Point, °C	287.3		Literature Value
Melting Point, °C	28.5		Literature Value
Density, 15°C	1.276 g/cm³		Literature Value
Viscosity, mPa.s (= cP), 30°C	10.3		Literature Value
100°C	2.5		Literature Value
200°C	1.0		Literature Value
Refractive Index, n_D, 30°C	1.48		Literature Value
Heat of Fusion, kJ/kg*	11.44		Literature Value
Dielectric Constant	43.3		Literature Value
Surface Tension, 30°C mN/m (= dyn/cm)	35.5		Literature Value

*To convert J to cal, divide by 4.184.

This product is also sold as Sulfolane-W, which is 3.0 wt. % water added to Sulfolane, Anhydrous. Phillips Chemical's Sulfolane-W meets all specifications for the Sulfolane process licensed by UOP, Inc.

Table 5.30: Solubility of Sulfolane in Various Chemical Compounds *(4)*

Chemical Compound	Temperature °C	Temperature °F	Grams Sulfolane/ 100 gms Chemical
Benzene	25.0	77	Miscible
Cyclohexane	25.0	77	0.4
2,3, Dimethylbutane	25.0	77	0.3
Hexene-1	25.0	77	1.0
Normal Hexane	25.0	77	0.3
Perchloroethylene	24.4	76	1.6
Toluene	25.0	77	Miscible
Mixed Xylenes	25.0	77	Miscible

Table 5.31: Solubility of Various Chemical Compounds in Sulfolane *(4)*

Chemical Compound	Temperature °C	Temperature °F	Grams Chemical/ 100 gms Sulfolane
Hydrogen Chloride (gas)	25.0	77	9.3
Ethyl Mercaptan	26.6	80	Miscible
Methyl Mercaptan	0.0	32	Miscible
Methyl Mercaptan	25.0	77	21.7*
Tertiary Dodecyl Mercaptan	25.0	77	2.0
Perchloroethylene	24.4	76	37.5
Polystyrene	199.8	392	0.02
Trichloroethylene	24.4	76	Miscible

*Test performed at atmospheric pressure, approx. 34° F above the normal boiling point (42.6° F) of methyl mercaptan.

Table 5.32: Thermal Stability of Sulfolane *(4)*

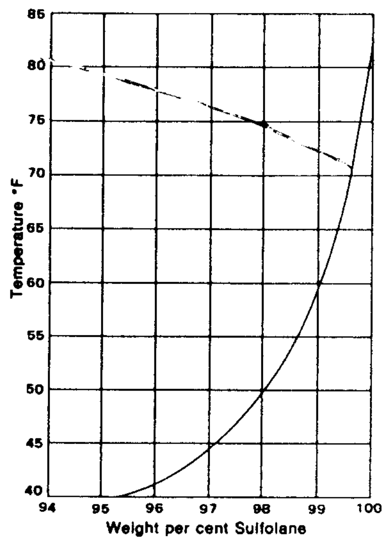
The tests summarized below were made with Sulfolane containing 10 mg of SO_2 per 250 ml. Phillips Test Method PPCo-6533-CZ.*

Temperature °C	Temperature °F	SO_2 (mg.) Liberated Per Hour From 250ml Sulfolane
180	356	0.6
200	392	2.8
220	428	3.3
240	464	24.1

FINDINGS: Sulfolane has good thermal stability up to and including 428° F, but has a rather sharp decomposition rate beyond this temperature. Excessive temperatures will cause Sulfolane to "crack" to a dark polymer and SO_2.

*Description of test method available on request.

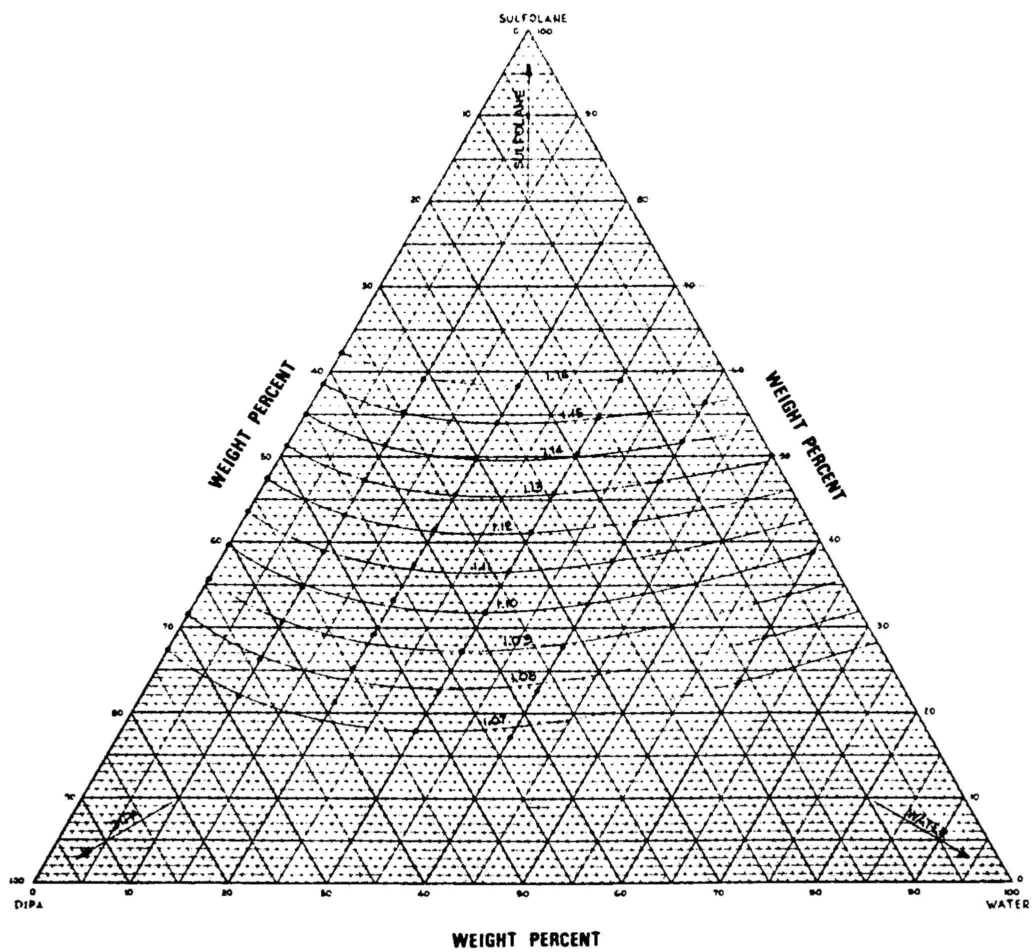
Table 5.33: Comparative Freezing Point Depression *(4)*



Freezing point curve for Sulfolane — water mixtures

Impurity	Mol. % Impurity Required to Lower Freezing Point 1°F
Normal Butylbenzene	0.098
2-Phenylpentane	0.103
Sulfolene	0.228
3-Methylsulfolane	0.189
Water	0.163

Table 5.34: Specific Gravity *(4)*



Monohydric Alcohols

METHANOL

Table 6.1: Physical Properties of Methanol *(70)*

Chemical Family	Alcohol
Chemical Formula	CH_3OH
Chemical Structure	H_3-C-OH
Chemical Abstract Service Number	67-56-1
Molecular Weight	32.04
Synonyms	Methyl Alcohol Carbinol Wood Alcohol
Auto Ignition Temperature, @ 760 mm Hg, °C (°F)	385 (725)
Boiling Point, @ 760 mm Hg, °C (°F)	64.7 (148.4)
Freezing Point, °C (°F)	−97.7 (−143.8)
Coefficient of Expansion,	
per °C @ 20°C	0.00119
per °F @ 68°F	0.00066
Critical Compressibility	0.224
Critical Density, g/cc (lb/cu ft)	0.272 (16.952)
Critical Pressure, Kg/cm² (PSIA)	81.12 (1153.95)
Critical Temperature, °C (°F)	240 (464)
Critical Volume, cc/g (cu ft/lb)	3.6829 (.05899)
Density, lb/gal @ 15.6°C (60°F)	6.63
Explosive Limits, % Volume in Air,	
Lower	6.0
Upper	36.5
Flash Point, Tag Closed Cup, °C (°F)	11 (52)
Heat of Formation, Liquid,	
@ 25°C, K cal/g mol	−57.021
@ 77°F, BTU/lb mol	-102.6×10^3
Heat of Formation, Vapor,	
@ 25°C, K cal/g mol	−48.08
@ 77°F, BTU/lb mol	-86.5×10^3
Heat of Fusion,	
@ −97°C, K cal/g mol	16.4
@ −142.6°F, BTU/lb mol	29.5
Refractive Index, N_D^{20}	1.3286
Solubility in Water, @ 20°C (68°F)	Completely Miscible

Table 6.2: Properties of Aqueous Solutions of Methanol *(31)*

Methanol Wt. %	Methanol Vol. %	Freezing Point °F.	Boiling Point °F.	Flash Point °F. (Closed Cup)	Density (g/ml.) at Various Temperatures 0°C.	10°C.	15°C.	20°C.	Viscosity (Millipoises) at Various Temperatures 25°C.	35°C.	45°C.	55°C.
0	0	32	212	—	.9999	.9997	.9993	.9982	8.9	7.2	5.9	5.1
10	12.35	21.7	197.2	130	.9842	.9834	.9824	.9815	11.8	9.2	7.4	6.2
20	24.33	5.9	187.3	107	.9725	.9700	.9681	.9666	14.1	10.9	8.6	7.1
30	35.95	−14.6	180.0	94	.9604	.9560	.9537	.9515	15.5	11.9	9.4	7.7
40	47.11	−39.1	174.2	84	.9459	.9403	.9372	.9345	15.8	12.3	9.7	7.9
50	57.71	−65.7	169.5	76	.9287	.9221	.9185	.9156	15.7	12.2	9.7	7.9
60	67.69	−101.2	165.6	69	.9090	.9018	.8978	.8946	14.0	10.9	8.8	7.2
70	76.98	−156.1	161.6	63	.8869	.8794	.8751	.8715	12.2	9.6	7.8	6.4
80	85.50	−175.0*	157.5	58	.8634	.8551	.8505	.8469	10.1	8.1	6.7	5.6
90	93.19	−171.4	153.0	53	.8374	.8287	.8240	.8202	7.9	6.5	5.5	4.6
100	100.0	−142.6	148.3	49	.8102	.8009	.7958	.7917	5.5	4.8	4.1	3.6

Wt. %	Vapor Pressure (mm.Hg) at Various Temperatures 20°C.	60°C.	100°C.	140°C.	Wt. % Methanol in Vapor at 760 mm.	Thermal Conductivity (cal/sec/cm²/°C/cm) at Various Temperatures 10°C.	40°C.	70°C.	Specific Heat at Various Temperatures 30°C.	50°C.	80°C.	100°C.
0	17.5	149	760	2700	0	.00138	.00149	.00160	0.990	0.994	1.000	1.004
10	28.0	206	1030	3640	43.4	.00126	.00135	.00145	1.015	1.022	1.032	1.039
20	35.5	258	1260	4300	61.2	.00115	.00122	.00129	1.000	1.014	1.035	1.049
30	41.5	307	1450	4780	70.5	.00105	.00110	.00115	0.974	0.997	1.031	1.054
40	46.5	350	1600	5200	76.5	.00096	.00098	.00100	0.947	0.979	1.026	1.057
50	52.0	390	1710	5620	81.0	.00088	.00088	.00088	0.888	0.928	0.988	1.028
60	59.0	427	1880	6040	84.8	.00079	.00078	.00076	0.821	0.869	0.941	0.990
70	66.5	462	2020	6470	88.5	.00072	.00069	.00066	0.764	0.820	0.905	0.961
80	75.5	503	2190	6970	92.2	.00065	.00061	.00057	0.726	0.790	0.886	0.951
90	87.0	557	2380	7550	96.0	.00059	.00054	.00049	0.665	0.737	0.846	0.918
100	99.0	620	2600	8150	100.0	.00053	.00048	.00043	0.626	0.706	0.826	0.887

*The eutectic point or minimum freezing temperature is approximately −128.7°C. (−199.7°F.) at a composition of 82.9% Wt. methanol (87.8% Vol.). In the vicinity of the eutectic, the solutions become vitreous and direct determinations of the freezing point are difficult to make.

Table 6.3: Freezing Points of Methanol-Water Solutions *(34)*



Table 6.4: Density and Specific Gravity of Methanol-Water Solutions at 15°C *(34)*

Methanol % by Weight	Methanol % by Volume	Density, 15/4°C	Specific Gravity, 15/15°C
0	0	0.99913	1.00000
1	1.253	0.99727	0.99813
2	2.502	0.99543	0.99629
3	3.746	0.99370	0.99456
4	4.986	0.99198	0.99284
5	6.222	0.99029	0.99115
6	7.454	0.98864	0.98950
7	8.682	0.98701	0.98786
8	9.906	0.98547	0.98632
9	11.128	0.98394	0.98479
10	12.345	0.98241	0.98326
11	13.559	0.98093	0.98178
12	14.779	0.97945	0.98030
13	15.977	0.97802	0.97887
14	17.181	0.97660	0.97745
15	18.382	0.97518	0.97602
16	19.579	0.97377	0.97461
17	20.773	0.97237	0.97321
18	21.963	0.97096	0.97180
19	23.149	0.96955	0.97039
20	24.322	0.96814	0.96898
21	25.512	0.96673	0.96757
22	26.688	0.96533	0.96614
23	27.860	0.96392	0.96475
24	29.029	0.96251	0.96334
25	30.193	0.96108	0.96191
26	31.354	0.95963	0.96046
27	32.510	0.95817	0.95900
28	33.662	0.95668	0.95751
29	34.809	0.95518	0.95601
30	35.952	0.95366	0.95499
31	37.091	0.95213	0.95295
32	38.224	0.95056	0.95138
33	39.352	0.94896	0.94978
34	40.476	0.94734	0.94816
35	41.594	0.94570	0.94652
36	42.708	0.94404	0.94486
37	43.816	0.94237	0.94319
38	44.919	0.94067	0.94148
39	46.016	0.93894	0.93975
40	47.109	0.93720	0.93801
41	48.195	0.93543	0.93624
42	49.277	0.93365	0.93446
43	50.353	0.93185	0.93266
44	51.422	0.93001	0.93081
45	52.486	0.92815	0.92895
46	53.544	0.92627	0.92707
47	54.595	0.92436	0.92516
48	55.639	0.92242	0.92322
49	56.678	0.92048	0.92128
50	57.712	0.91852	0.91931
51	58.739	0.91653	0.91732
52	59.759	0.91451	0.91530
53	60.773	0.91248	0.91327
54	61.781	0.91044	0.91123
55	62.783	0.90839	0.90918
56	63.778	0.90631	0.90709
57	64.767	0.90421	0.90499
58	65.750	0.90210	0.90268
59	66.725	0.89996	0.90074
60	67.693	0.89781	0.89859
61	68.654	0.89563	0.89640
62	69.607	0.89341	0.89418
63	70.552	0.89117	0.89194
64	71.490	0.88890	0.88967
65	72.420	0.88662	0.88739
66	73.344	0.88433	0.88510
67	74.252	0.88203	0.88279
68	75.172	0.87971	0.88047
69	76.077	0.87739	0.87815
70	76.976	0.87507	0.87583
71	77.864	0.87271	0.87346
72	78.746	0.87033	0.87108
73	79.618	0.86792	0.86867
74	80.480	0.86546	0.86621
75	81.336	0.86300	0.86375
76	82.182	0.86051	0.86125
77	83.022	0.85801	0.85875
78	83.855	0.85551	0.85625
79	84.680	0.85300	0.85374
80	85.499	0.85048	0.85122
81	86.310	0.84794	0.84867
82	87.110	0.84536	0.84609
83	87.899	0.84274	0.84347
84	88.677	0.84009	0.84082
85	89.448	0.83742	0.83814
86	90.212	0.83475	0.83547
87	90.968	0.83207	0.83279
88	91.716	0.82937	0.83009
89	92.456	0.82667	0.82738
90	93.118	0.82396	0.82467
91	93.912	0.82124	0.82195
92	94.627	0.81849	0.81920
93	95.326	0.81568	0.81639
94	96.017	0.81285	0.81365
95	96.697	0.80999	0.81069
96	97.370	0.80713	0.80783
97	98.036	0.80428	0.80498
98	98.696	0.80143	0.80212
99	99.351	0.79859	0.79928
100	100.000	0.79577	0.79646

Table 6.5: Density and Specific Gravity of Methanol-Water Solutions at 30°C *(34)*

Methanol % by Weight	Methanol % by Volume	Density, 30/4°C	Specific Gravity, 30/30°C
0	0.000	0.9957	1.0000
1	1.271	0.9939	0.9982
2	2.538	0.9921	0.9964
3	3.800	0.9903	0.9946
4	5.057	0.9886	0.9929
5	6.310	0.9868	0.9911
6	7.559	0.9850	0.9893
7	8.802	0.9832	0.9874
8	10.042	0.9815	0.9857
9	11.278	0.9798	0.9840
10	12.511	0.9782	0.9824
11	13.738	0.9765	0.9807
12	14.962	0.9749	0.9791
13	16.182	0.9733	0.9775
14	17.398	0.9717	0.9759
15	18.610	0.9701	0.9743
16	19.820	0.9686	0.9728
17	21.024	0.9670	0.9712
18	22.224	0.9654	0.9696
19	23.420	0.9638	0.9680
20	24.612	0.9622	0.9664
21	25.799	0.9606	0.9647
22	26.983	0.9590	0.9631
23	28.162	0.9574	0.9615
24	29.338	0.9558	0.9599
25	30.509	0.9542	0.9583
26	31.676	0.9526	0.9567
27	32.839	0.9510	0.9551
28	33.998	0.9494	0.9535
29	35.149	0.9477	0.9518
30	36.296	0.9460	0.9501
31	37.439	0.9443	0.9484
32	38.577	0.9426	0.9467
33	39.706	0.9408	0.9449
34	40.831	0.9390	0.9431
35	41.952	0.9372	0.9412
36	43.067	0.9354	0.9394
37	44.179	0.9336	0.9376
38	45.285	0.9318	0.9358
39	46.387	0.9300	0.9340
40	47.479	0.9281	0.9321
41	48.572	0.9263	0.9303
42	49.654	0.9244	0.9284
43	50.732	0.9225	0.9265
44	51.805	0.9206	0.9246
45	52.867	0.9186	0.9226
46	53.925	0.9166	0.9206
47	54.977	0.9146	0.9185
48	56.024	0.9126	0.9165
49	57.059	0.9105	0.9144
50	58.089	0.9084	0.9123
51	59.121	0.9064	0.9103
52	60.140	0.9043	0.9082
53	61.148	0.9021	0.9060
54	62.149	0.8999	0.9038
55	63.146	0.8977	0.9016
56	64.136	0.8955	0.8994
57	65.114	0.8932	0.8971
58	66.093	0.8910	0.8948
59	67.059	0.8887	0.8925
60	68.019	0.8864	0.8902
61	68.981	0.8842	0.8880
62	69.929	0.8819	0.8857
63	70.872	0.8796	0.8834
64	71.809	0.8773	0.8811
65	72.731	0.8749	0.8787
66	73.656	0.8726	0.8764
67	74.566	0.8702	0.8740
68	75.471	0.8678	0.8715
69	76.369	0.8654	0.8691
70	77.261	0.8630	0.8667
71	78.146	0.8606	0.8643
72	79.017	0.8581	0.8618
73	79.881	0.8556	0.8593
74	80.729	0.8530	0.8567
75	81.580	0.8505	0.8542
76	82.425	0.8480	0.8517
77	83.253	0.8454	0.8491
78	84.085	0.8429	0.8465
79	84.900	0.8403	0.8439
80	85.719	0.8378	0.8414
81	86.522	0.8352	0.8388
82	87.317	0.8326	0.8362
83	88.095	0.8299	0.8335
84	88.867	0.8272	0.8308
85	89.631	0.8245	0.8281
86	90.389	0.8218	0.8253
87	91.139	0.8191	0.8226
88	91.883	0.8164	0.8199
89	92.608	0.8136	0.8171
90	93.327	0.8108	0.8143
91	94.038	0.8080	0.8115
92	94.730	0.8051	0.8086
93	95.415	0.8022	0.8057
94	96.080	0.7992	0.8027
95	96.737	0.7962	0.7996
96	97.400	0.7933	0.7967
97	98.054	0.7904	0.7938
98	98.702	0.7875	0.7909
99	99.355	0.7847	0.7881
100	100.000	0.7819	0.7853

Table 6.6: Resultant Volume When Methanol and Water are Mixed *(31)*

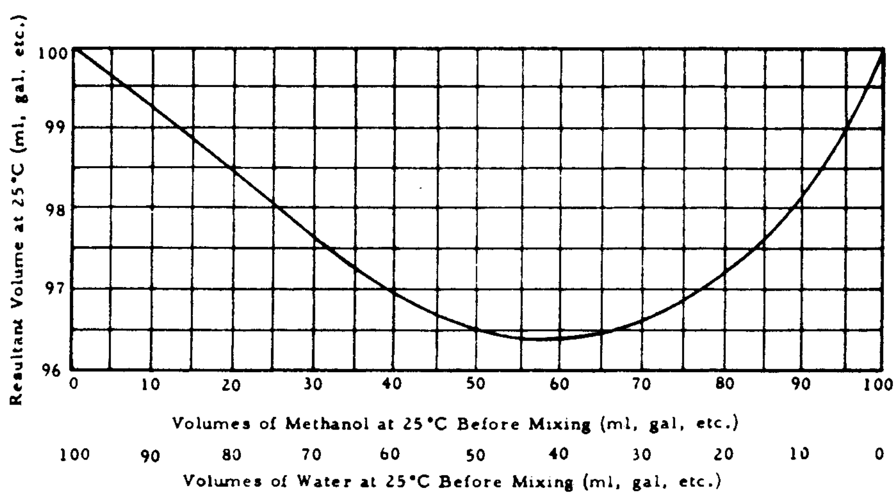


Table 6.7: Solubility of Methanol in Gasoline from 15° to 30°C *(31)*

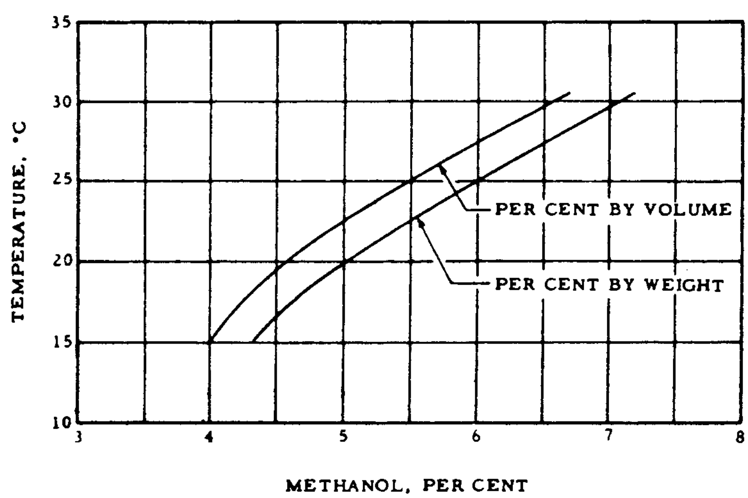


Table 6.8: Liquid Density of Methanol *(70)*

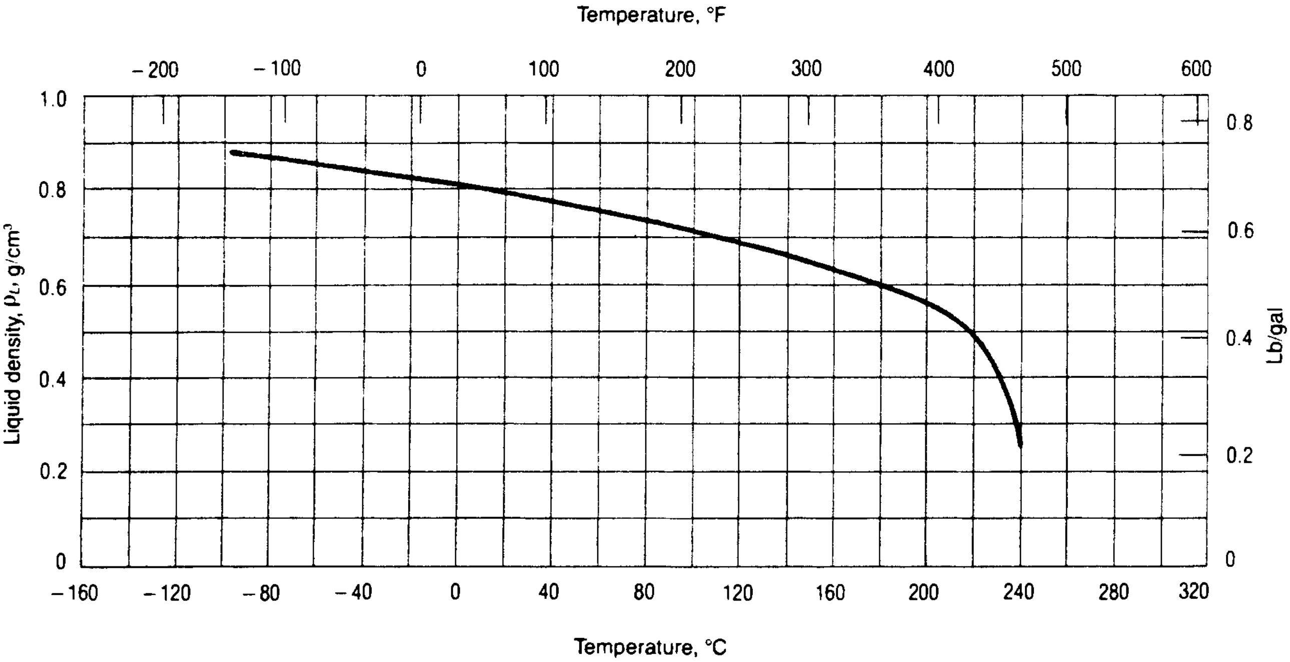


Table 6.9: Liquid Heat Capacity of Methanol *(70)*

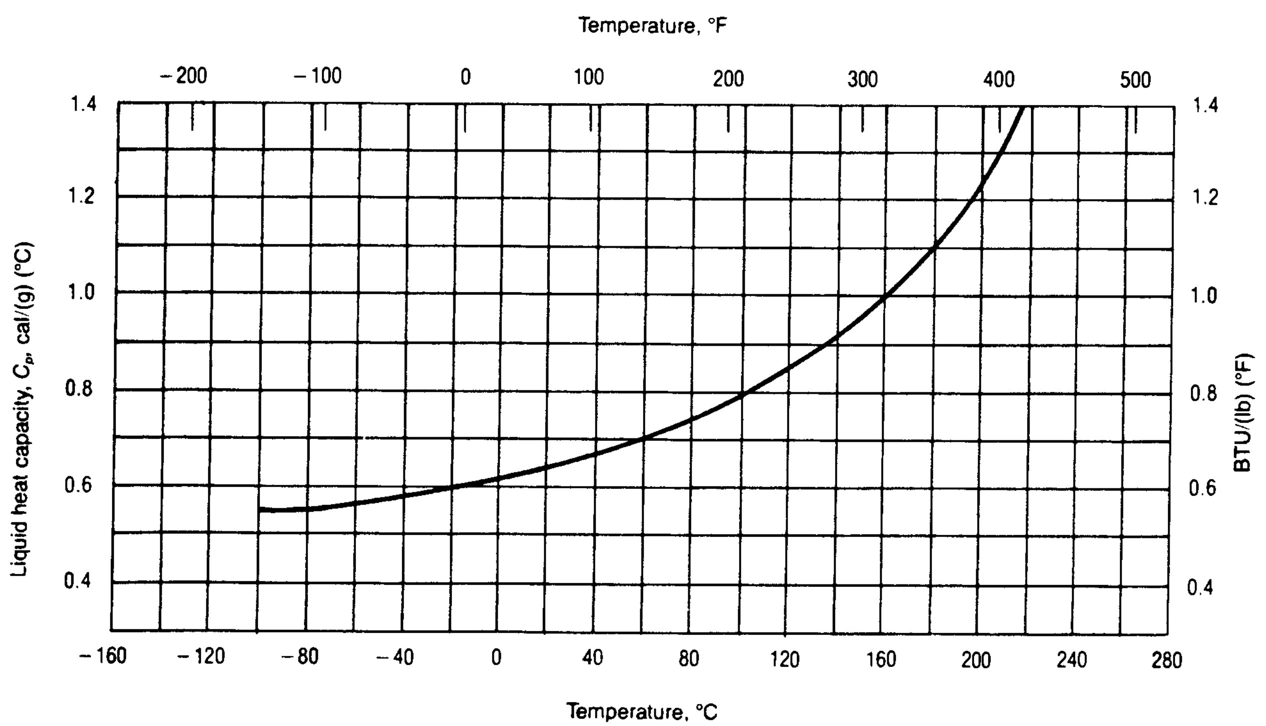


Table 6.10: Vapor Heat Capacity of Methanol *(70)*

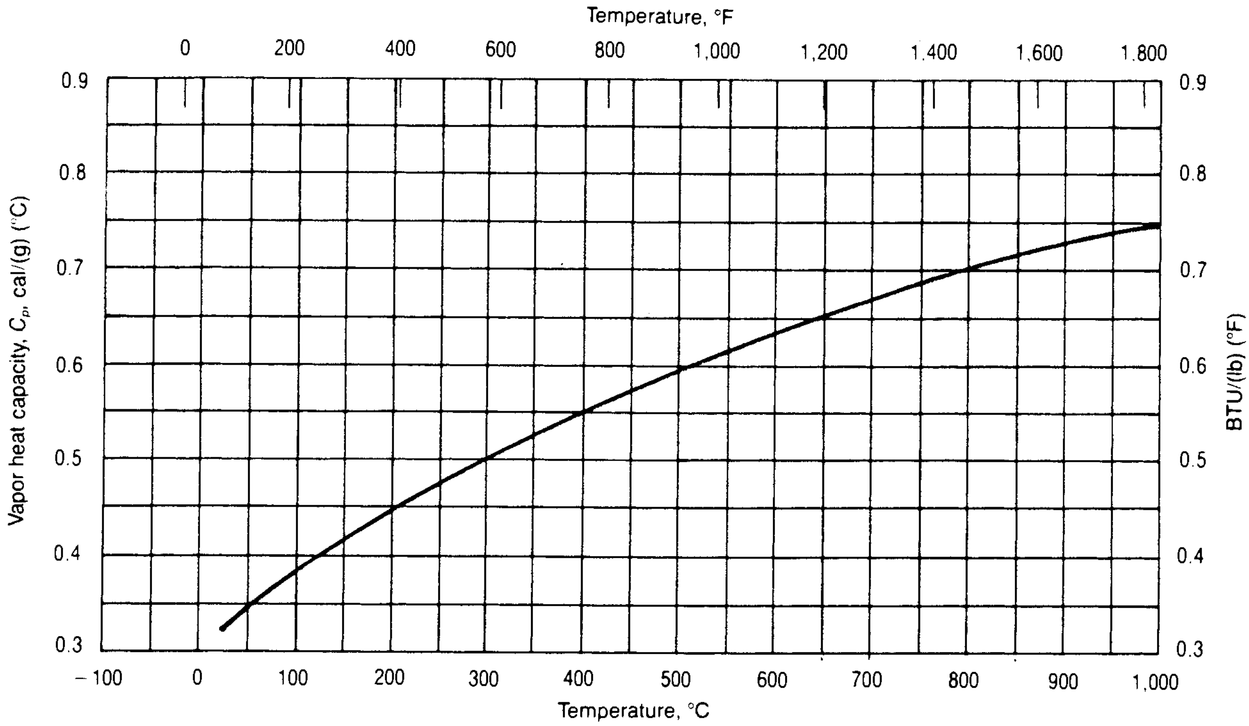


Table 6.11: Heat of Vaporization of Methanol *(70)*

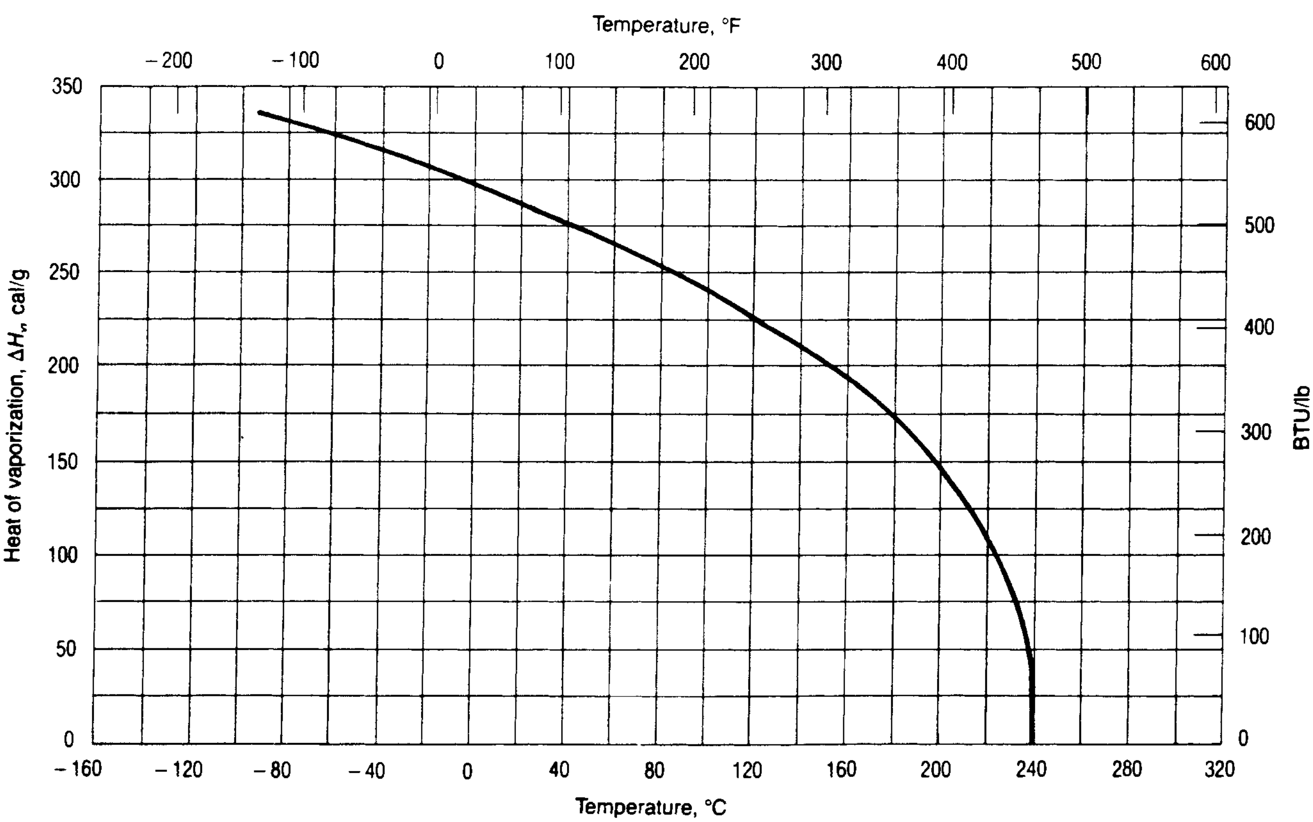


Table 6.12: Surface Tension of Methanol *(70)*

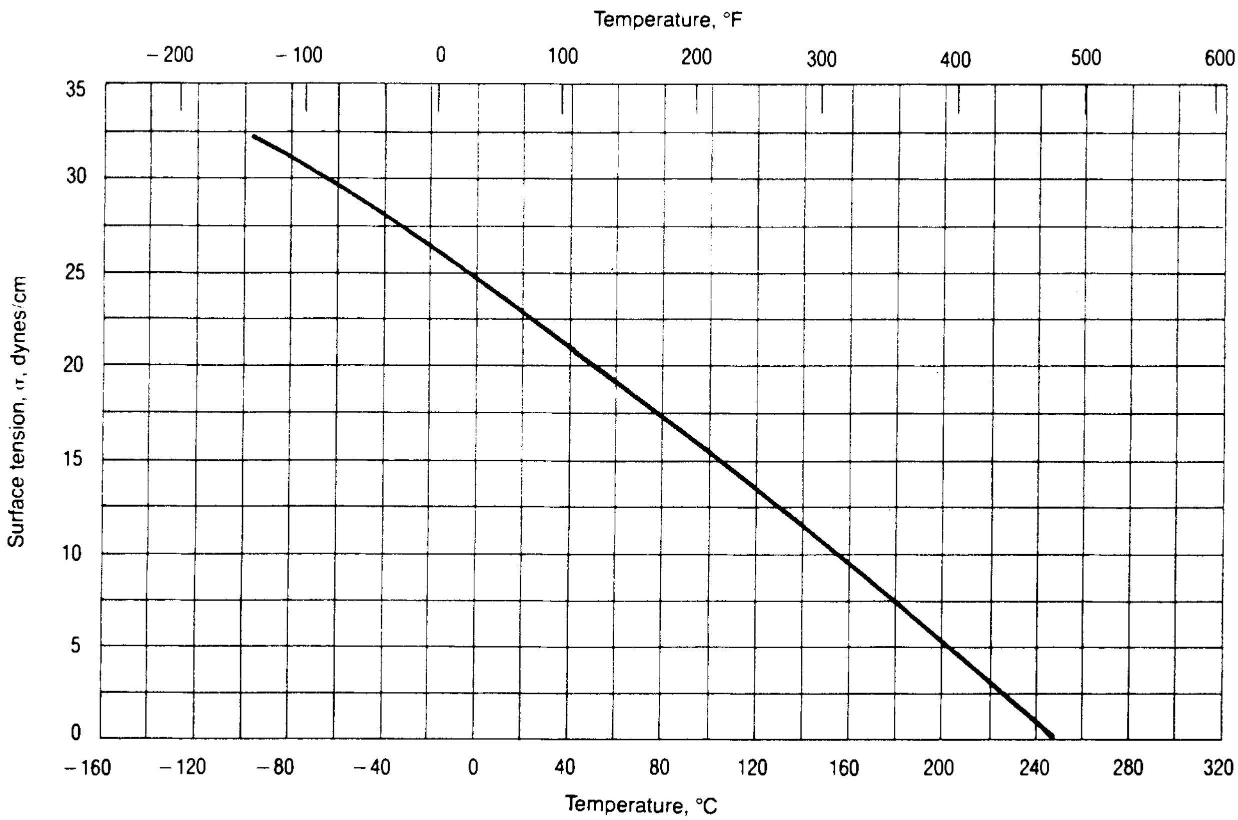


Table 6.13: Liquid Thermal Conductivity of Methanol *(70)*

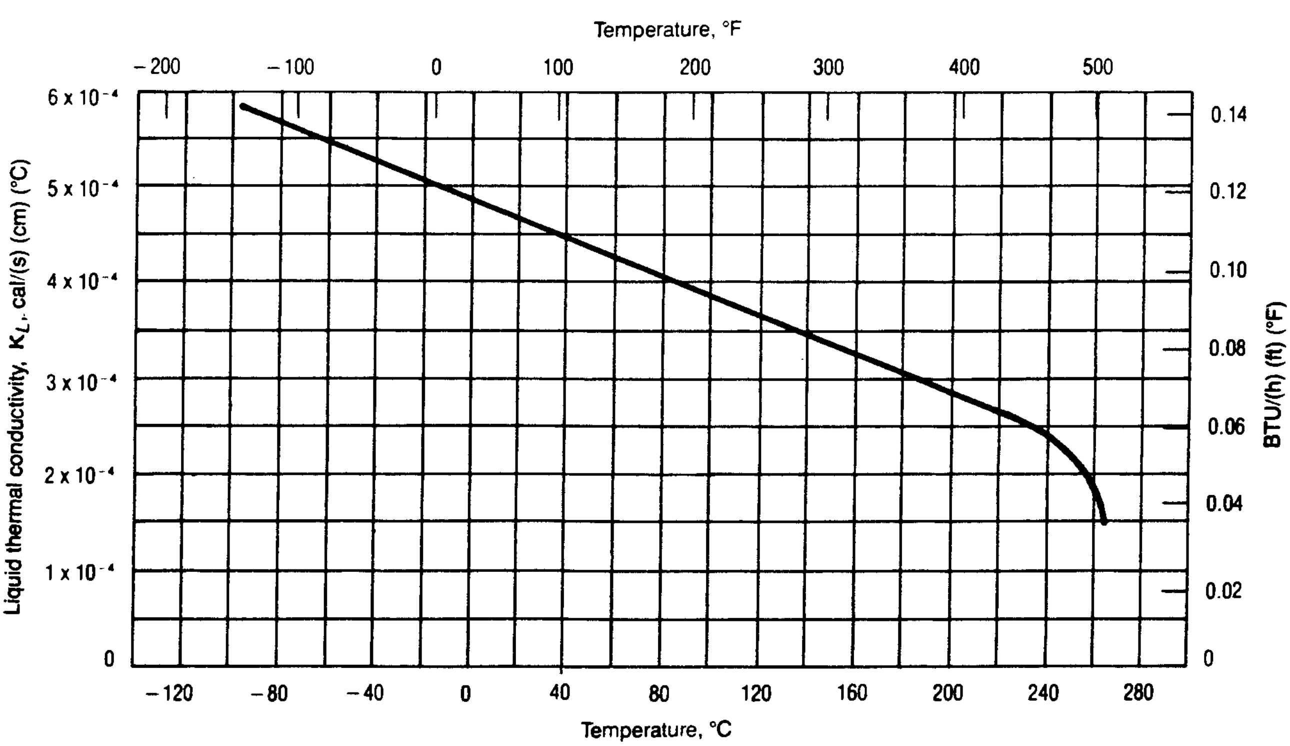


Table 6.14: Vapor Thermal Conductivity of Methanol *(70)*

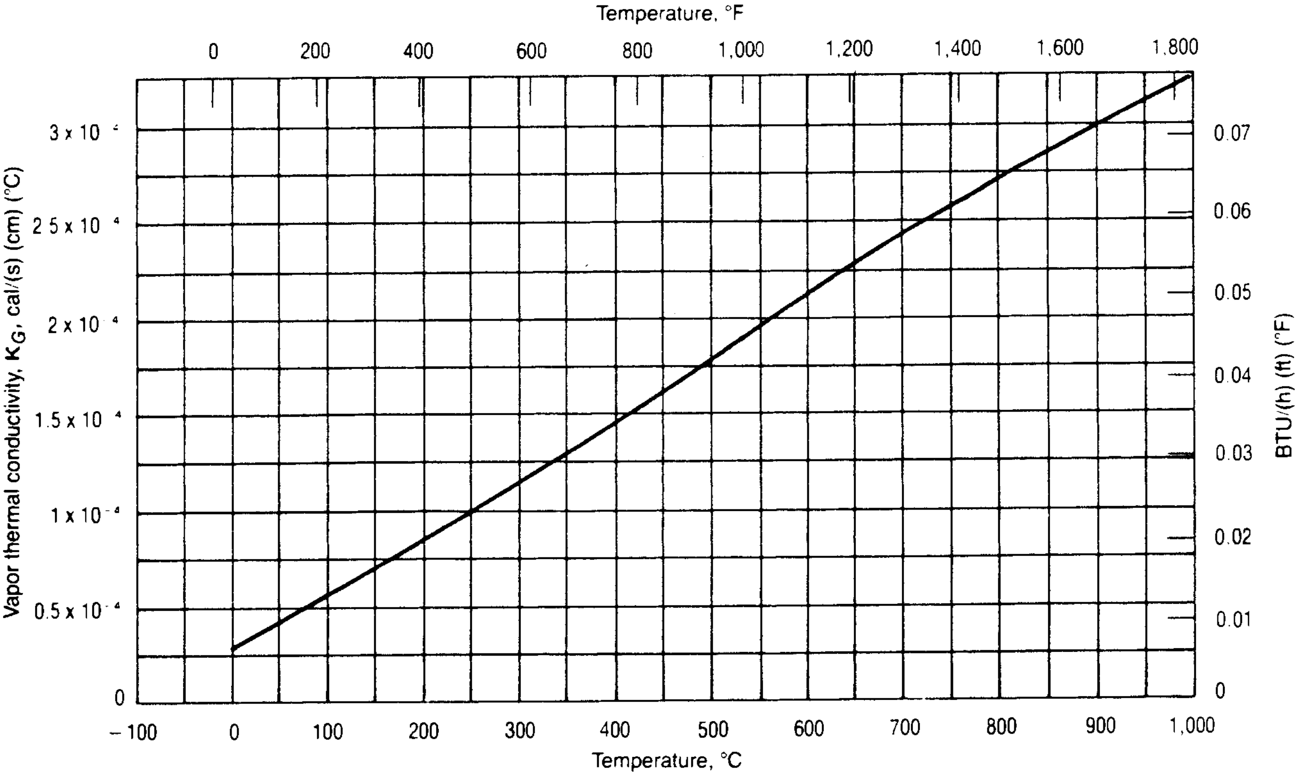


Table 6.15: Vapor Pressure of Methanol *(70)*

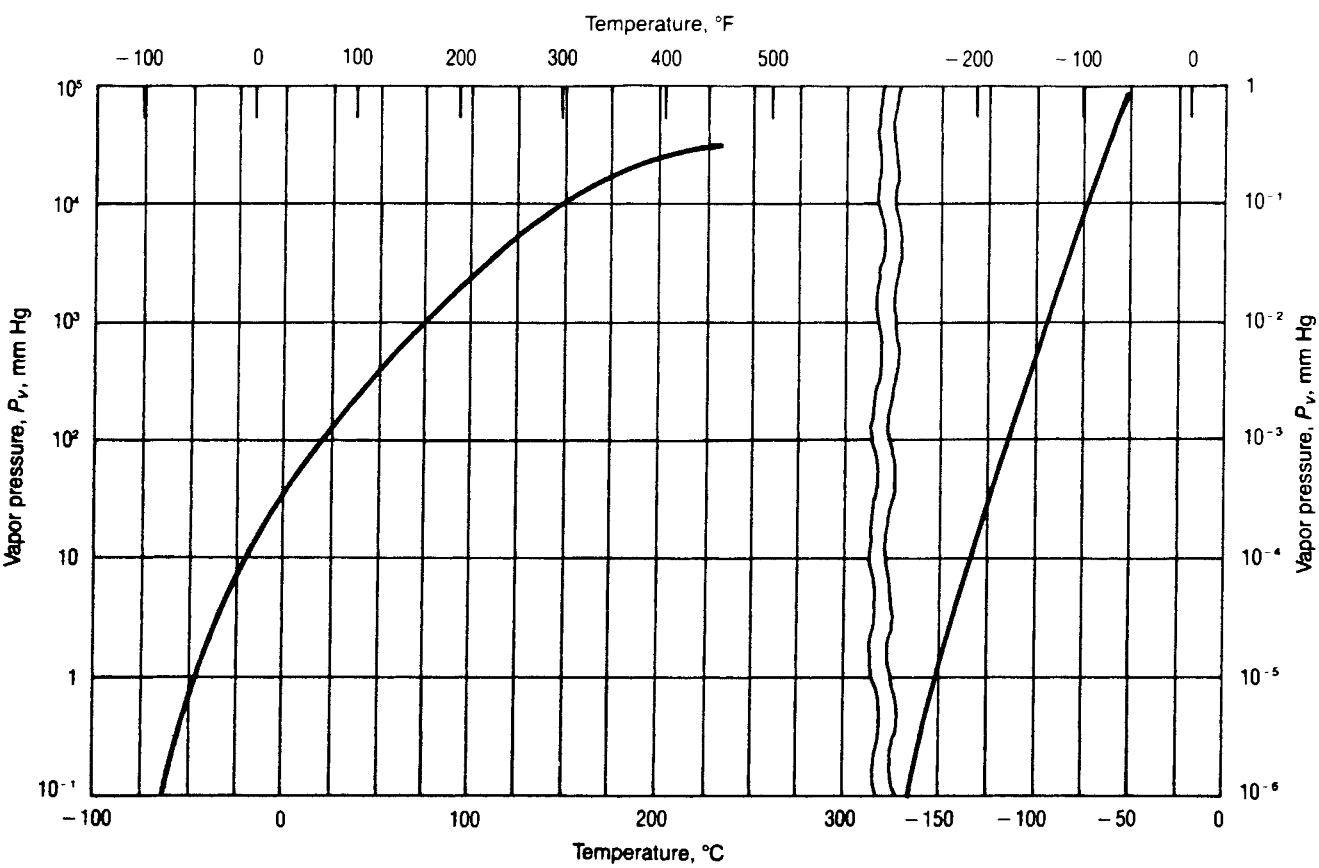


Table 6.16: Vapor Viscosity of Methanol *(70)*

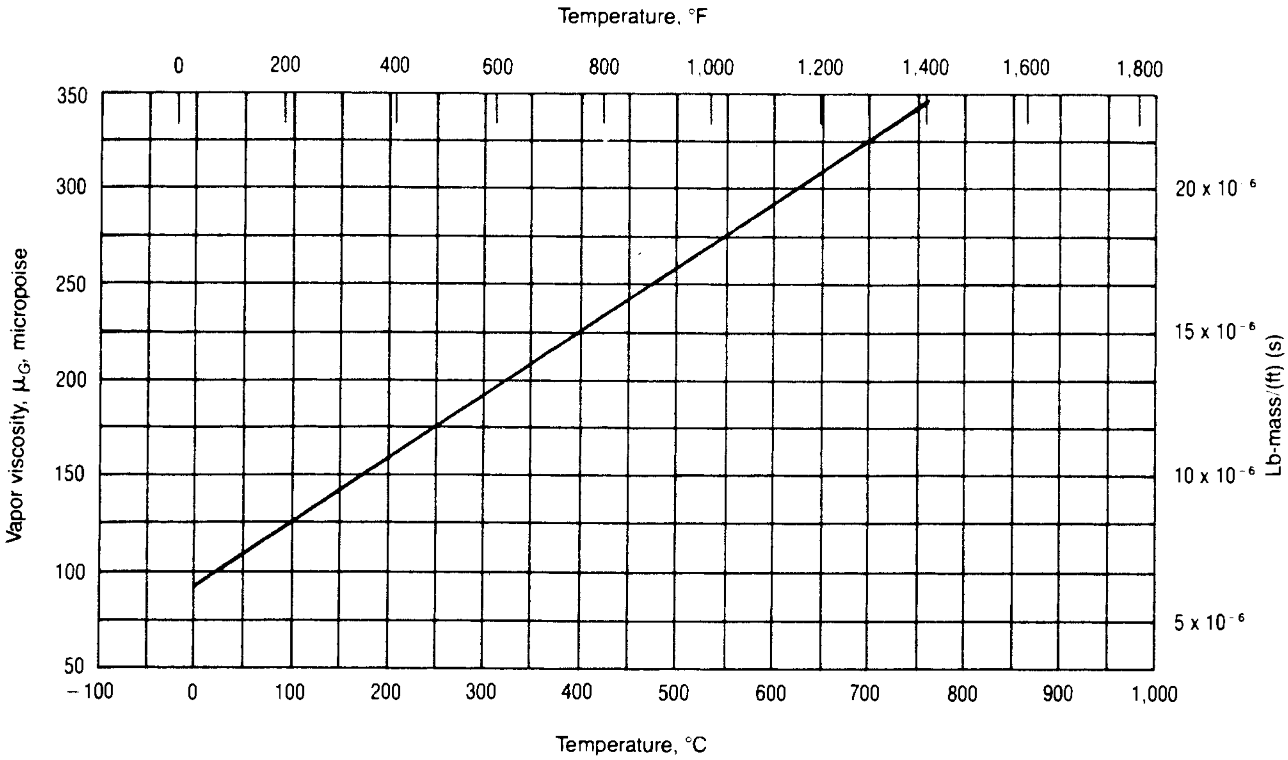


Table 6.17: Liquid Viscosity of Methanol *(70)*

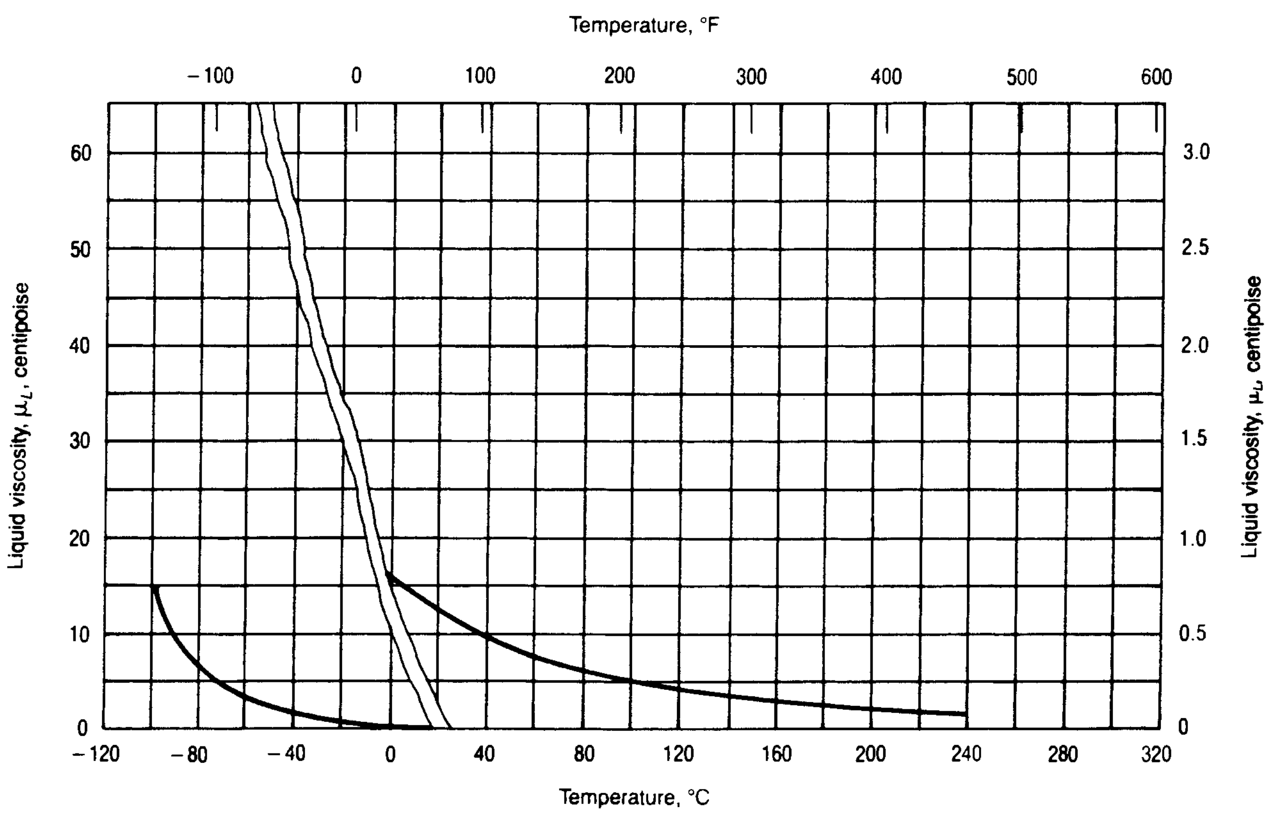


Table 6.18: Azeotropes of Methanol *(31)*

METHANOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C.
88	Acetone	55.5
81	Acetonitrile	63.5
38.7	Acrylonitrile	61.4
50	tert-Amyl methyl ether	62.3
60.5	Benzene	58.3
77.5	Biallyl	47.1
41	1-Bromobutane	63.7
58.5	2-Bromobutane	61.5
95	Bromoethane	35
58	1-Bromo-2-methylpropane	61.6
76	2-Bromo-2-methylpropane	55.6
79	1-Bromopropane	54.5
85.5	2-Bromopropane	49.0
88	cis-1-Bromopropene	48
85	trans-1-Bromopropene	50.8
89	2-Bromopropene	42.7
79.5	3-Bromopropene	54.0
30	2-Butanone	63.5
64.6	Butyl methyl ether	56.3
86	Carbon disulfide	37.7
79.4	Carbon tetrachloride	55.7
71.5	1-Chlorobutane	57.2
80	2-Chlorobutane	52.7
87	Chloroform	53.5
43	1-Chloro-3-methylbutane	62.0
65	Chloromethyl methyl ether	56.0
77	1-Chloro-2-methylpropane	53.1
90	2-Chloro-2-methylpropane	43.8
90	1-Chloropropane	40.6
94	2-Chloropropane	33.4
97	2-Chloropropene	22.0
90	3-Chloropropene	39.9
61.2	1,3-Cyclohexadiene	56.4
57.5	1,4-Cyclohexadiene	58.0
60	Cyclohexane	55.9
86	Cyclopentane	38.8
18	1,1-Dibromoethane	64.2
38	trans-1,2-Dibromoethylene	64.1
50	2,3-Dichloro-1,3-butadiene	61.5
88.5	1,1-Dichloroethane	59.0
68	1,2-Dichloroethane	61.0
87	cis-1,2-Dichloroethylene	51.5
47	1,2-Dichloropropane	62.9
79	2,2-Dichloropropane	55.5
75	1,2-Dichloro-1-propene	56.5
35	Diethoxymethane	63.2
10	1,2-Dimethoxyethylene	63.5
75.8	Dimethyl acetal	57.5
80	2,3-Dimethylbutane	45.0
40	2,5-Dimethylhexane	61.0
54	Ethyl acetate	77.1
44	Ethyl butyl ether	62.6
65	Ethylene dichloride	59.5
79	Ethylene sulfide	47.0
84	Ethyl formate	51.0
43	Ethyl nitrate	61.8
76	Ethyl propyl ether	55.5
38	Ethyl sulfide	61.2
68	Fluorobenzene	59.7
93	Furan	30.5
48.5	n-Heptane	59.1
83	Iodoethane	55.0
50	1-Iodopropane	63.1
62	2-Iodopropane	61.0
38	3-Iodopropene	63.5
60	Isobutyraldehyde	62.7
20	Isopropyl acetate	64.5
67	Isopropyl formate	57.2
92.1	Methylal	41.8
80.5	Methyl acetate	54.0
46	Methyl acrylate	62.5
68	Methyl borate	54.6
93	2-Methyl-2-butene	31.8
97	3-Methyl-1-butene	19.8
85	Methyl tert-butyl ether	51.6
30	Methyl carbonate	62.7
46	Methylcyclohexane	59.2
68	Methylcyclopentane	51.3
65	Methylcyclopentene	53.0
77.7	2-Methylfuran	51.5
25	Methyl isobutyrate	64.0
52.5	Methyl propionate	62.5
88	Methyl propyl ether	38.0
87	Methyl sulfide	34.5
91	n-Pentane	30.8
9.3	α-Pinene	64.6
28	Propyl ether	63.8
49.8	Propyl formate	61.9
28	Octane	63.0
36.5	Tetrachloroethylene	63.8
45	Thiophene	59.6
31	Toluene	63.8
78.3	1,1,1-Trichloroethane	56.0
3	1,1,2-Trichloroethane	64.5
62	Trichloroethylene	59.3
47	2,2,4-Trimethylpentane	59.4

METHANOL FORMS TERNARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C.
43.5	Acetone	51.1
40.5	Cyclohexane	
5.8	Acetone	53.7
76.8	Methyl acetate	
40	Carbon disulfide	33.9
50	Bromoethane	
55	Carbon disulfide	35.6
38	Methylal	
47	Chloroform	47.0
30	Acetone	
57.2	Methyl acetate	37.0
46.5	Carbon disulfide	
48.6	Methyl acetate	50.8
33.6	Cyclohexane	
27	Methyl acetate	45.0
59	Hexane	
5.3	Water	67.9
13.5	Methyl chloroacetate	

ETHYL ALCOHOL

Table 6.19: Physical Properties of Anhydrous Ethyl Alcohol *(31)*

Acidity as acetic acid	0.0015% by wt. max.
Boiling point at 760 mm Hg	78.32°C
dt/dp at 760 mm Hg	0.0334°C/mm Hg
Coefficient of cubical expansion	0.00060 per 1°F
Color, Pt-Co scale	10 max.
Critical pressure	63.1 atm
Critical temperature	243.1°C
Density at 25°C	0.7851 g/ml
Dielectric constant at 20°C	25.7
Dipole moment, $\mu \times 10^{18}$	1.70 μ
Electrical conductivity at 25°C	1.35×10^{-9} ohm^{-1} cm^{-1}
Explosive range	3.28 - 19%
Fire hazard	Dangerous when exposed to heat or flame
Flash point, Tag open cup	61°F
Free energy of formation, $\Delta F°$ at 25°C	-40.2 kcal/mole
Freezing point	-114.1°C
Heat capacity, Cp, Liquid at 25°C	0.581 cal/g
Cp, Vapor, 90°C, 1 atm	0.406 cal/(g) (°C)
Cv, Vapor, 90°C, 1 atm	0.359 cal/(g) (°C)
Heat of combustion	328 kcal/mole
Heat of formation, Liquid, ΔH at 25°C	-64.7 kcal/mole
Heat of solution in Water at 13°C	2.54 kcal/mole solute
Heat of solution of Water in Ethyl Alcohol, mole fraction of Water	
0.640 at 77°C	-0.018
0.843 at 79.2°C	-0.038
Latent heat of fusion	24.9 cal/g
Latent heat of vaporization at 78.3°C	204.3 cal/g
MAC	1000 ppm in air
Melting point	-114.4°C
Molecular weight	46.07
Non-volatile matter	Not more than 0.0025 gram when 100 ml are evaporated and heated to constant weight at 100°C to 110°C
Reducing substances	At least 25 minutes permanganate time at 15°C
Refractive index at 25°C, n_D	1.3596
Specific gravity at 15.56°C (60/60°F)	0.7937
Specific heat at 20°C	0.61 cal/g
Specific tension at 25°C	22.1 dynes/cm
Thermal conductivity, k, at 68°F	0.105 (Btu) (ft) (sq ft) (°F)
Toxicity	Moderately toxic by ingestion and inhalation
Vapor pressure at 20°C	44.0 mm Hg
Viscosity at 20°C	1.22 centipoises
Weight per gallon at 20°C	6.61 lbs

Table 6.20: Physical Properties of 95% Ethanol *(31)*

Acidity as acetic acid	0.0025 g/100 ml, max.
Color, Pt-Co scale	10 max.
Distillation range at 760 mm Hg	77°C - 80°C
Non-volatile matter	Not more than 0.0025 gram when 100 ml are evaporated and heated to constant weight at 100°C to 110°C
Permanganate time	30 minutes, min.
Reducing substances	At least 25 minutes permanganate time at 15°C
Relative evaporation rate, n-Butyl Acetate = 100	230
Specific gravity at 15.56 (60/60°F)	0.8160
Weight per gallon at 20°C	6.76 lbs

Table 6.21: Properties and Specifications of Ethyl Alcohol *(30)*

Specifications

	Units	190°	200°	Test Method
Ethyl Alcohol, minimum strength	vol %	95	99.9	IRS Gauging Manual
Acidity as Acetic Acid, maximum	g/100 ml	0.0025	0.0025	ASTM D 1613
Non-Volatile Matter, maximum	g/100 ml	0.0025	0.0025	ASTM D 1353
Permanganate Time, minimum	minutes	50	30	Quantum test
Specific Gravity @ 60°F (15.56°C), maximum		0.816	0.794	ASTM D 891
Color, maximum	Pt-Co	10	10	ASTM D 1209
Odor	Free from foreign odors			Organoleptic

Typical Properties

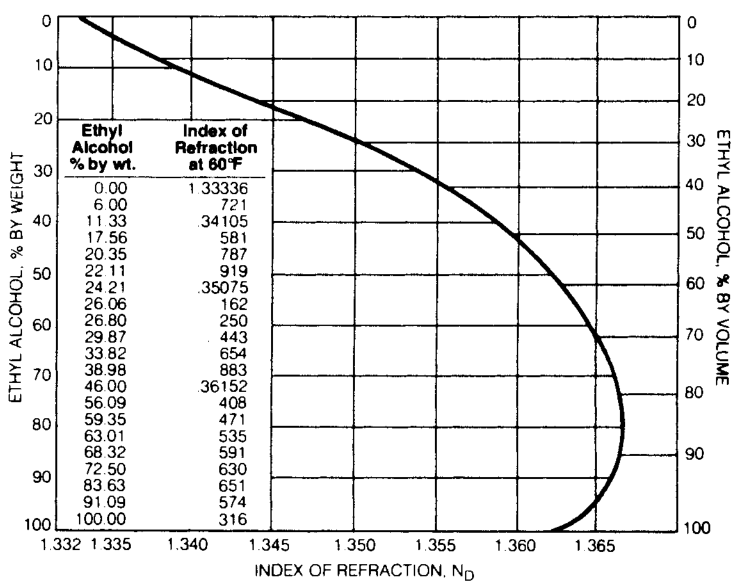
	Units	190°	200°
Boiling Point	°C	78.3	78.4
	°F	172.9	173.1
Coefficient of Expansion			
Per °C		0.0011	0.0011
Per °F		0.00062	0.00062
Flash Point			
ASTM D 1310	°C	21	18
(Tag Open Cup)	°F	69	65
ASTM D 56	°C	17	14
(Tag Closed Cup)	°F	62	57
Weight per Gallon @ 60 °F (15.56 °C)	lbs	6.794	6.610
Water Solubility	soluble in all proportions		

Table 6.22: Conversion Table—Weight and Volume Percent of Ethyl Alcohol in Ethyl Alcohol-Water Mixtures *(30)*

% Alcohol By Volume at 60°F	% to be Converted	% Alcohol By Weight	% Alcohol By Volume at 60F	% to be Converted	% Alcohol By Weight	% Alcohol By Volume at 60°F	% to be Converted	% Alcohol By Weight	% Alcohol By Volume at 60°F	% to be Converted	% Alcohol By Weight
1.257	1	0.795	31.555	26	21.285	58.844	51	43.428	82.121	76	68.982
2.510	2	1.593	32.719	27	22.127	59.852	52	44.374	82.967	77	70.102
3.758	3	2.392	33.879	28	22.973	60.854	53	45.326	83.805	78	71.234
5.002	4	3.194	35.033	29	23.820	61.850	54	46.283	84.636	79	72.375
6.243	5	3.998	36.181	30	24.670	62.837	55	47.245	85.459	80	73.526
7.479	6	4.804	37.323	31	25.524	63.820	56	48.214	86.275	81	74.686
8.712	7	5.612	38.459	32	26.382	64.798	57	49.187	87.083	82	75.858
9.943	8	6.422	39.590	33	27.242	65.768	58	50.167	87.885	83	77.039
11.169	9	7.234	40.716	34	28.104	66.732	59	51.154	88.678	84	78.233
12.393	10	8.047	41.832	35	28.971	67.690	60	52.147	89.464	85	79.441
13.613	11	8.862	42.944	36	29.842	68.641	61	53.146	90.240	86	80.662
14.832	12	9.679	44.050	37	30.717	69.586	62	54.152	91.008	87	81.897
16.047	13	10.497	45.149	38	31.596	70.523	63	55.165	91.766	88	83.144
17.259	14	11.317	46.242	39	32.478	71.455	64	56.184	92.517	89	84.408
18.469	15	12.138	47.328	40	33.364	72.380	65	57.208	93.254	90	85.689
19.676	16	12.961	48.407	41	34.254	73.299	66	58.241	93.982	91	86.989
20.880	17	13.786	49.480	42	35.150	74.211	67	59.279	94.700	92	88.310
22.081	18	14.612	50.545	43	36.050	75.117	68	60.325	95.407	93	89.652
23.278	19	15.440	51.605	44	36.955	76.016	69	61.379	96.103	94	91.025
24.472	20	16.269	52.658	45	37.865	76.909	70	62.441	96.787	95	92.423
25.662	21	17.100	53.705	46	38.778	77.794	71	63.511	97.459	96	93.851
26.849	22	17.933	54.746	47	39.697	78.672	72	64.588	98.117	97	95.315
28.032	23	18.768	55.780	48	40.622	79.544	73	65.674	98.759	98	96.820
29.210	24	19.604	56.808	49	41.551	80.410	74	66.768	99.386	99	98.381
30.388	25	20.443	57.830	50	42.487	81.269	75	67.870	100.000	100	100.000

Values from Tables 5 and 6, Bureau of Standards Circular No. 19

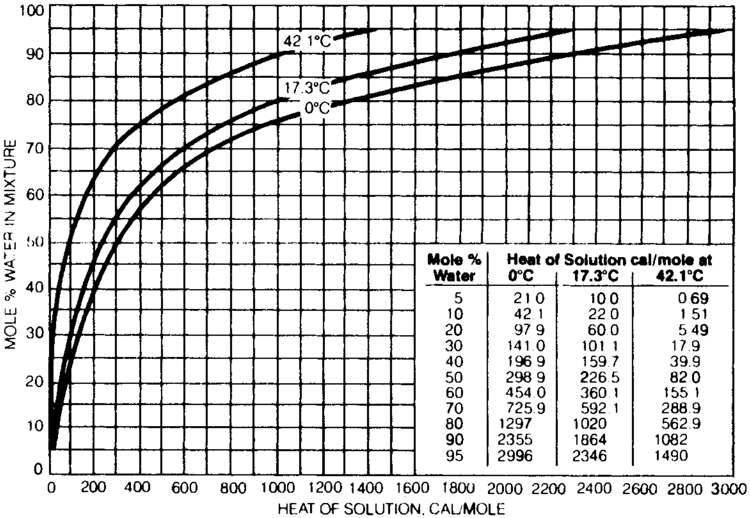
Table 6.23: Index of Refraction of Ethyl Alcohol-Water Mixtures at 60°F *(30)*



Ethyl Alcohol % by wt.	Index of Refraction at 60°F
0.00	1.33336
6.00	721
11.33	.34105
17.56	581
20.35	787
22.11	919
24.21	.35075
26.06	162
26.80	250
29.87	443
33.82	654
38.98	883
46.00	.36152
56.09	408
59.35	471
63.01	535
68.32	591
72.50	630
83.63	651
91.09	574
100.00	316

Data from International Critical Tables

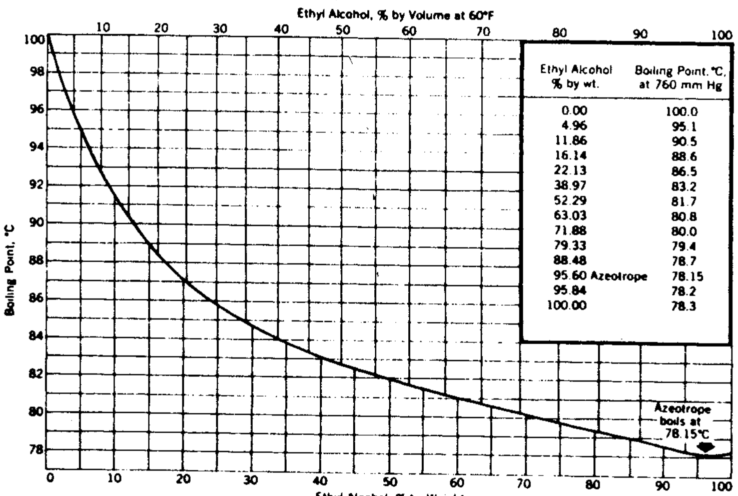
Table 6.24: Heat of Solution of Ethyl Alcohol in Water *(30)*



Mole % Water	Heat of Solution cal/mole at 0°C	17.3°C	42.1°C
5	21.0	10.0	0.69
10	42.1	22.0	1.51
20	97.9	60.0	5.49
30	141.0	101.1	17.9
40	196.9	159.7	39.9
50	298.9	226.5	82.0
60	454.0	360.1	155.1
70	725.9	592.1	288.9
80	1297	1020	562.9
90	2355	1864	1082
95	2996	2346	1490

Data from International Critical Tables
BTU/lb mole = 1.8 cal/g mole

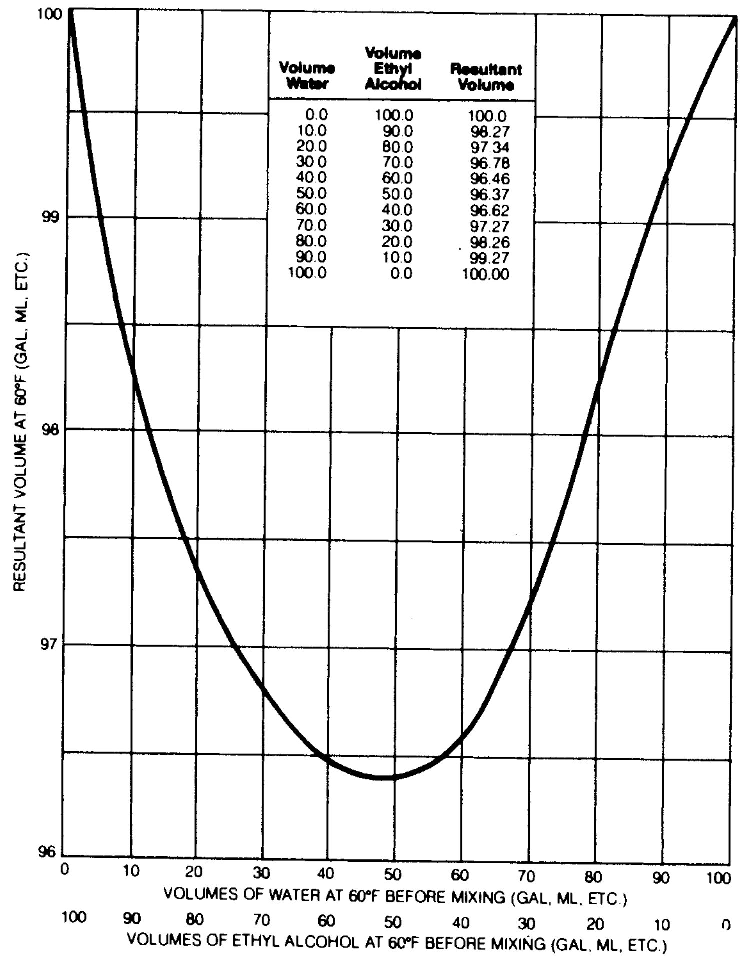
Table 6.26: Boiling Points of Ethyl Alcohol–Water Solutions *(34)*



Ethyl Alcohol % by wt.	Boiling Point, °C, at 760 mm Hg
0.00	100.0
4.96	95.1
11.86	90.5
16.14	88.6
22.13	86.5
38.97	83.2
52.29	81.7
63.03	80.8
71.88	80.0
79.33	79.4
88.48	78.7
95.60 Azeotrope	78.15
95.84	78.2
100.00	78.3

Calculated from mole per cent data given in International Critical Tables

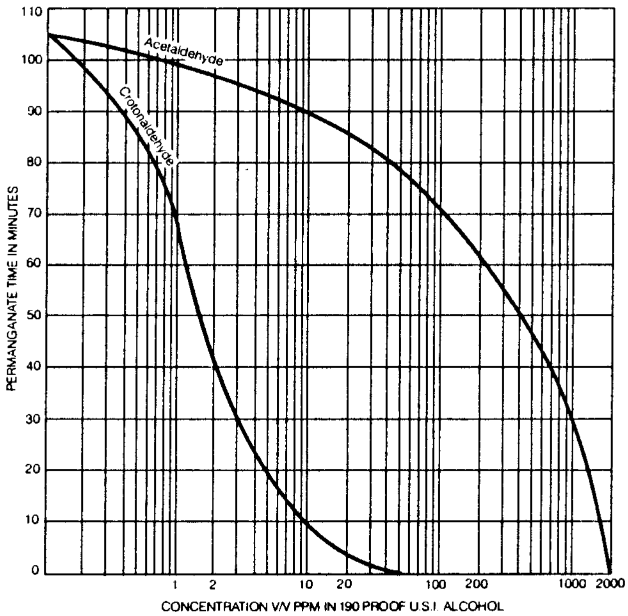
Table 6.25: Resultant Volume When Ethyl Alcohol and Water are Mixed *(30)*



Volume Water	Volume Ethyl Alcohol	Resultant Volume
0.0	100.0	100.0
10.0	90.0	98.27
20.0	80.0	97.34
30.0	70.0	96.78
40.0	60.0	96.46
50.0	50.0	96.37
60.0	40.0	96.62
70.0	30.0	97.27
80.0	20.0	98.26
90.0	10.0	99.27
100.0	0.0	100.00

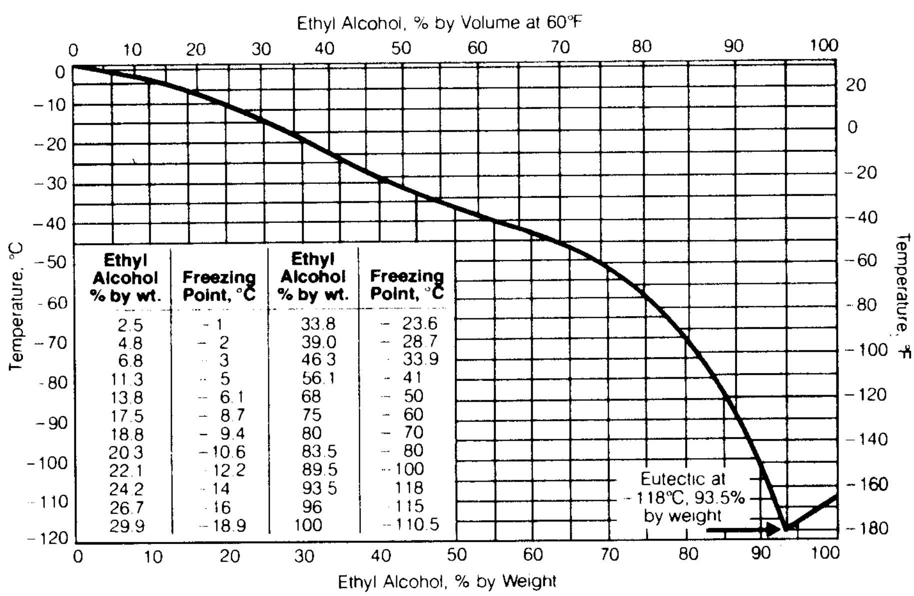
Ibert Mellan, 'Industrial Solvents Handbook', 2nd Edition, Noyes Data Corporation (1977)

Table 6.27: Permanganate Time Test *(30)*



Ref. U.S. Industrial Chemicals Company, Tuscola, IL.

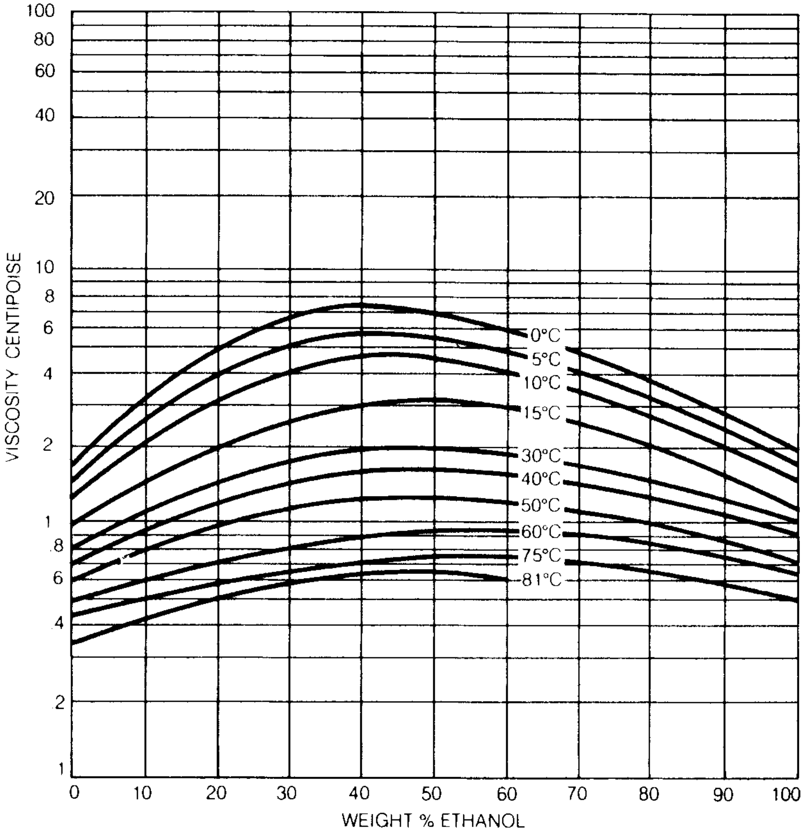
Table 6.28: Freezing Points of Ethyl Alcohol-Water Mixtures *(30)*



Ethyl Alcohol % by wt.	Freezing Point, °C	Ethyl Alcohol % by wt.	Freezing Point, °C
2.5	-1	33.8	-23.6
4.8	-2	39.0	-28.7
6.8	-3	46.3	-33.9
11.3	-5	56.1	-41
13.8	-6.1	68	-50
17.5	-8.7	75	-60
18.8	-9.4	80	-70
20.3	-10.6	83.5	-80
22.1	-12.2	89.5	-100
24.2	-14	93.5	118
26.7	-16	96	-115
29.9	-18.9	100	-110.5

Ibert Mellan, 'Industrial Solvents Handbook', 2nd Ed., Noyes Data Corporation (1977)

Table 6.29: Viscosity of Ethyl Alcohol-Water Mixtures *(30)*



National Bureau of Standards Bulletin, 14 (1918), 59
U.S. Industrial Chemical Company, Tuscola, Illinois

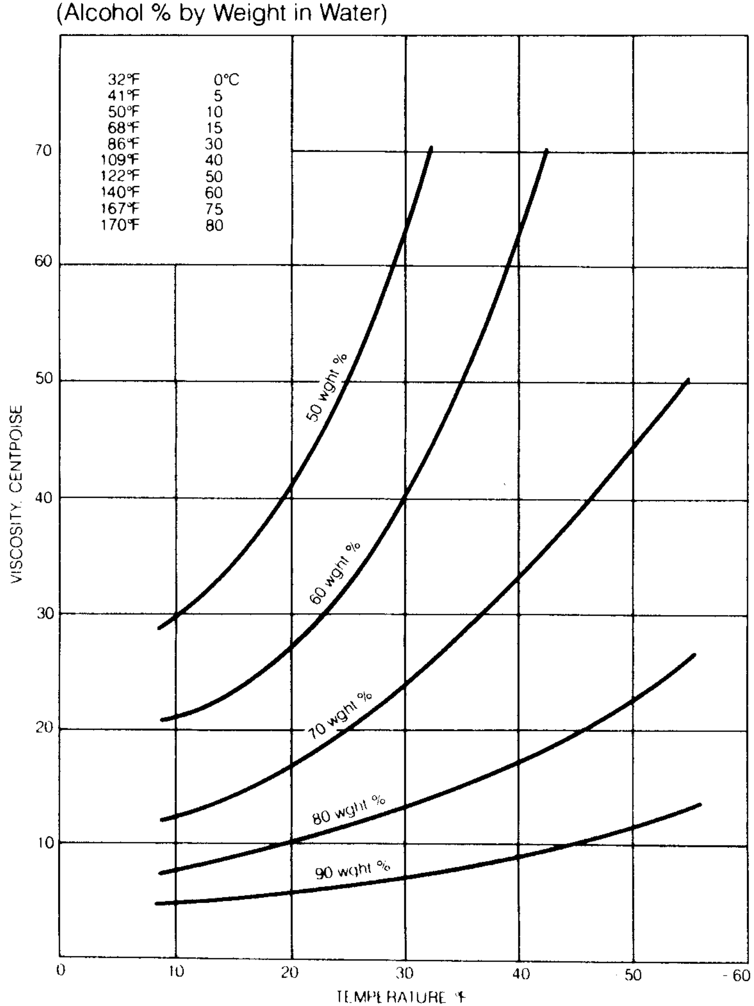


Table 6.30: Flash Point of Aqueous Ethyl Alcohol Solutions °C and °F vs Vol % Ethanol *(30)*

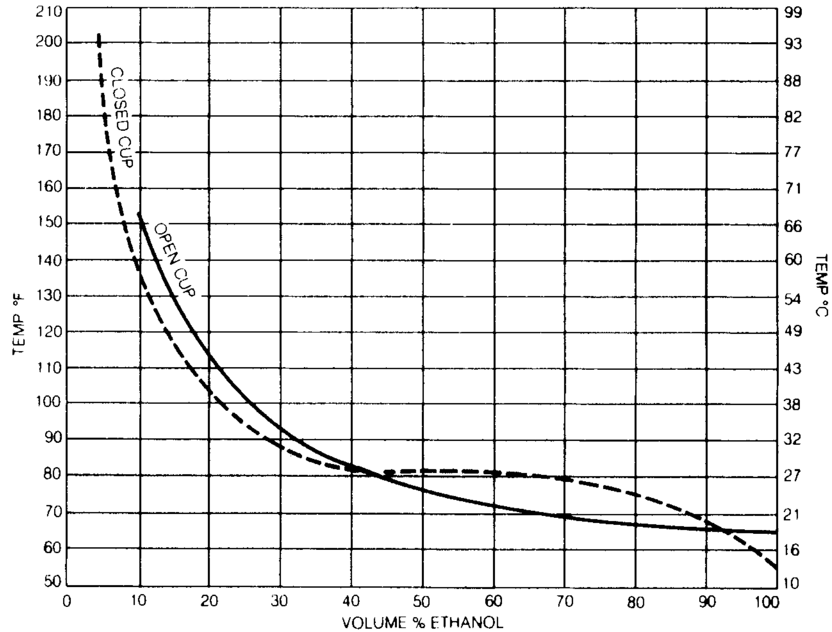
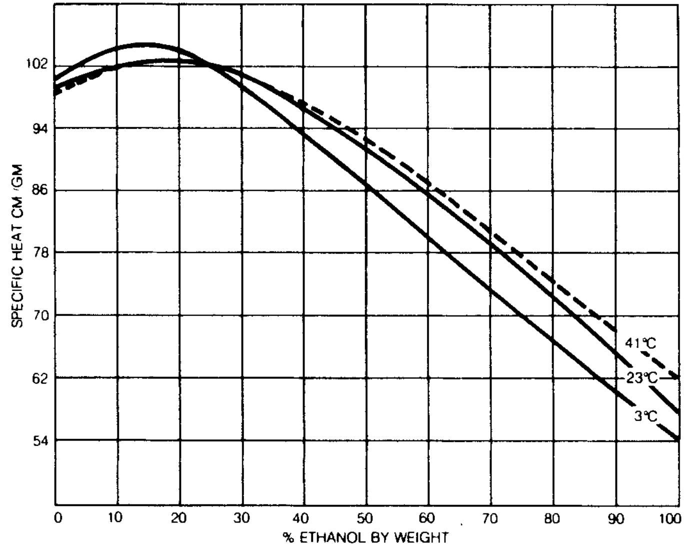
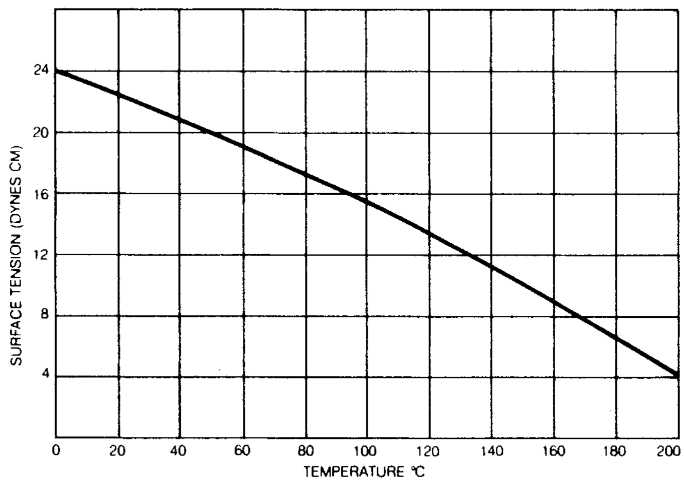


Table 6.31: Specific Heat of Aqueous Solutions of Ethanol *(30)*



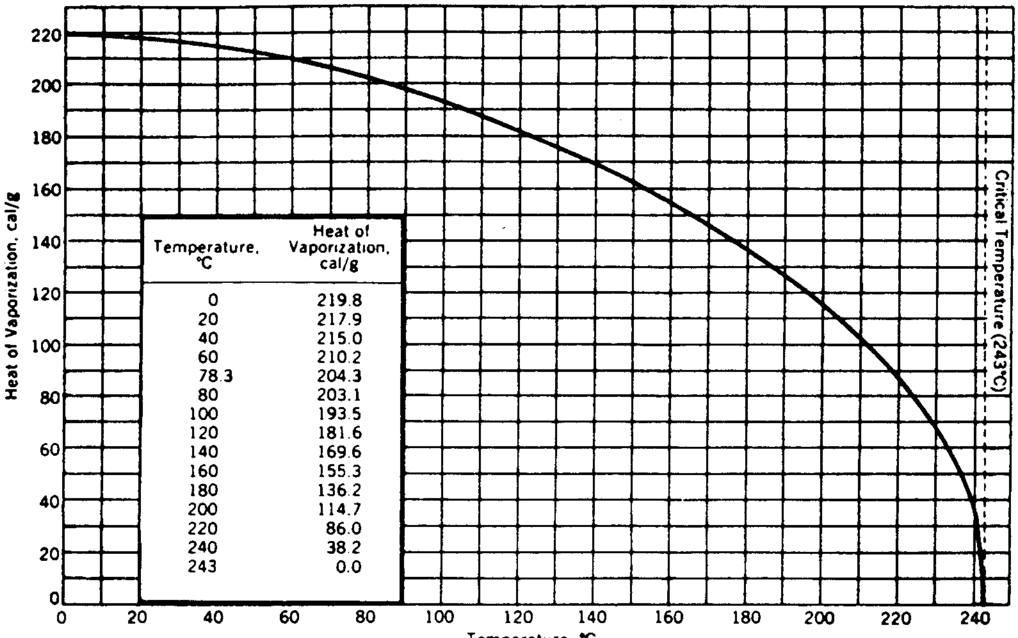
Ibert Mellan, 'Industrial Solvents', 2nd Edition, Reinhold Publishing Corp. (1950)

Table 6.32: Surface Tension of Pure Ethanol at Various Temperatures *(30)*



Ibert Mellan, 'Industrial Solvents', 2nd Edition, Reinhold Publishing Corp. (1950)

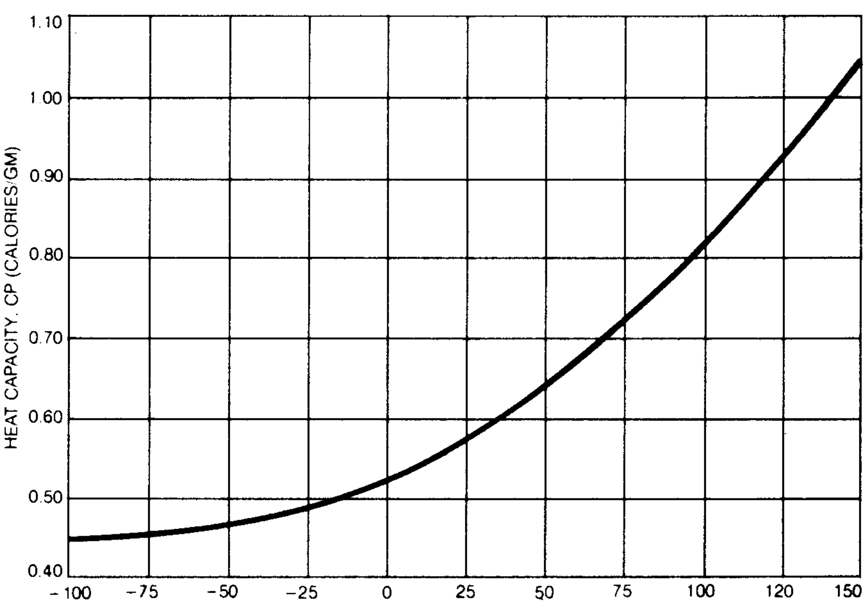
Table 6.33: Latent Heat of Vaporization of Ethyl Alcohol *(34)*



Temperature, °C	Heat of Vaporization, cal/g
0	219.8
20	217.9
40	215.0
60	210.2
78.3	204.3
80	203.1
100	193.5
120	181.6
140	169.6
160	155.3
180	136.2
200	114.7
220	86.0
240	38.2
243	0.0

Data from International Critical Tables
BTU/lb=1.8 x cal/g

Table 6.34: Heat Capacity of Ethyl Alcohol at Various Temperatures *(30)*



Data from International Critical Tables

Table 6.35: Volumetric Equivalents *(30)*

The following table will be helpful in the preparation of reports showing disposition of 190 proof and anhydrous (200 proof) tax-free and specially denatured alcohol.

Fluid Ounces	Milliliters	Wine Gallons	Proof Gallons	
			190 proof	200 proof
1	30.	0.008	0.015	0.016
2	59.	.016	.030	.031
3	89.	.023	.045	.047
4	118.	.031	.059	.062
5	148.	.039	.074	.078
6	177.	.047	.088	.094
7	207.	.055	.103	.109
8	237.	.063	.119	.125
9	266.	.070	.134	.140
10	296.	.078	.149	.156
11	325.	.086	.164	.172
12	355.	.094	.179	.187
13	385.	.102	.194	.203
14	414.	.109	.209	.218
15	444.	.117	.224	.234
16 (1 pint)	473.	.125	.238	.250
32 (1 quart)	946.	250	.475	.500
64 (2 quarts)	1892	.500	.950	1.000
96	2839	.750	1.425	1.500
128 (1 U.S. gallon)	3785	1.000	1.900	2.000
		5.000	9.500	10.000
		30.000	57.000	60.000
		54.000	102.600	108.000
		55.000	104.500	110.000

Table 6.36: Ethyl Alcohol-Water Mixtures *(30)*

Corresponding values for proof, parts by vo ume of water and alcohol, weight % alcohol and specific gravity in air.

U.S. PROOF degrees at 60°F	PARTS BY VOLUME* OF		WEIGHT % ETHYL ALCOHOL	SPECIFIC GRAVITY		
	WATER	ETHYL ALCOHOL		at 60°/60°F (15.56°/15.56°C)	at 68°/68°F (20°/20°C)	at 77°/77°F (25°/25°C)
0	100.00	0.0	0.00	1.0000	1.0000	1.0000
1	99.53	0.5	0.40	.9992	.9992	.9992
2	99.06	1.0	0.80	.9985	.9985	.9985
3	98.58	1.5	1.19	.9978	.9978	.9978
4	98.12	2.0	1.59	.9970	.9970	.9970
5	97.65	2.5	1.99	.9963	.9963	.9963

*The parts by volume of water and the parts by volume of ethyl alcohol do not add to unity (100) at any one proof reading, because of the shrinkage in volume which occurs when ethyl alcohol and water are mixed. The *parts by volume* of ethyl alcohol are the same as *percent by volume* of ethyl alcohol used to determine proof for tax purposes. Ethyl alcohol proof, by legal definition, is twice the percent by volume.

(continued)

Table 6.36: (continued)

U.S. PROOF degrees at 60°F	PARTS BY VOLUME* OF		WEIGHT % ETHYL ALCOHOL	SPECIFIC GRAVITY		
	WATER	ETHYL ALCOHOL		at 60°/60°F (15.56°/15.56°C)	at 68°/68°F (20°/20°C)	at 77°/77°F (25°/25°C)
6	97.18	3.0	2.39	.9956	.9956	.9956
7	96.71	3.5	2.79	.9949	.9949	.9948
8	96.24	4.0	3.19	.9942	.9942	.9941
9	95.78	4.5	3.60	.9935	.9935	.9934
10	95.31	5.0	4.00	.9928	.9928	.9927
11	94.85	5.5	4.40	.9921	.9921	.9921
12	94.39	6.0	4.80	.9915	.9914	.9914
13	93.93	6.5	5.21	.9908	.9908	.9907
14	93.46	7.0	5.61	.9902	.9902	.9901
15	93.01	7.5	6.02	.9896	.9895	.9894
16	92.55	8.0	6.42	.9890	.9889	.9888
17	92.09	8.5	6.83	.9884	.9883	.9882
18	91.63	9.0	7.23	.9878	.9876	.9875
19	91.18	9.5	7.64	.9872	.9870	.9869
20	90.72	10.0	8.05	.9866	.9864	.9863
21	90.27	10.5	8.46	.9860	.9858	.9856
22	89.81	11.0	8.86	.9854	.9852	.9850
23	89.36	11.5	9.27	.9848	.9846	.9844
24	88.90	12.0	9.68	.9843	.9840	.9838
25	88.45	12.5	10.09	.9837	.9835	.9832
26	88.00	13.0	10.50	.9832	.9829	.9826
27	87.55	13.5	10.91	.9826	.9823	.9820
28	87.10	14.0	11.32	.9821	.9817	.9814
29	86.65	14.5	11.73	.9816	.9812	.9808
30	86.20	15.0	12.14	.9810	.9806	.9802
31	85.75	15.5	12.55	.9805	.9801	.9796
32	85.30	16.0	12.96	.9800	.9797	.9790
33	84.85	16.5	13.37	.9794	.9790	.9784
34	84.40	17.0	13.79	.9789	.9784	.9778
35	83.95	17.5	14.20	.9784	.9779	.9773
36	83.50	18.0	14.61	.9779	.9773	.9767
37	83.06	18.5	15.03	.9774	.9768	.9761
38	82.61	19.0	15.44	.9769	.9763	.9756
39	82.16	19.5	15.85	.9764	.9757	.9750
40	81.72	20.0	16.27	.9759	.9752	.9744
41	81.27	20.5	16.68	.9754	.9747	.9739
42	80.82	21.0	17.10	.9749	.9741	.9733
43	80.38	21.5	17.52	.9744	.9736	.9727
44	79.93	22.0	17.93	.9739	.9731	.9721

*The parts by volume of water and the parts by volume of ethyl alcohol do not add to unity (100) at any one proof reading, because of the shrinkage in volume which occurs when ethyl alcohol and water are mixed. The *parts by volume* of ethyl alcohol are the same as *percent by volume* of ethyl alcohol used to determine proof for tax purposes. Ethyl alcohol proof, by legal definition, is twice the percent by volume.

(continued)

Table 6.36: (continued)

U.S. PROOF degrees at 60°F	PARTS BY VOLUME* OF		WEIGHT % ETHYL ALCOHOL	SPECIFIC GRAVITY		
	WATER	ETHYL ALCOHOL		at 60°/60°F (15.56°/15.56°C)	at 68°/68°F (20°/20°C)	at 77°/77°F (25°/25°C)
45	79.48	22.5	18.35	.9734	.9725	.9715
46	79.03	23.0	18.77	.9729	.9720	.9710
47	78.58	23.5	19.19	.9724	.9714	.9704
48	78.14	24.0	19.60	.9718	.9708	.9698
49	77 69	24.5	20.02	.9713	.9703	.9692
50	77.24	25.0	20.44	.9708	.9697	.9686
51	76.79	25.5	20.86	.9703	.9691	.9679
52	76.34	26.0	21.28	.9697	.9686	.9673
53	75.89	26.5	21.71	.9692	.9680	.9667
54	75.44	27.0	22.13	.9687	.9674	.9661
55	74.98	27.5	22.55	.9681	.9668	.9654
56	74.53	28.0	22.97	.9676	.9662	.9648
57	74.08	28.5	23.40	.9670	.9656	.9642
58	73.62	29.0	23.82	.9664	.9650	.9635
59	73.17	29.5	24.24	.9659	.9644	.9629
60	72.72	30.0	24.67	.9653	.9638	.9622
61	72.26	30.5	25.10	.9647	.9632	.9616
62	71.81	31.0	25.52	.9641	.9626	.9609
63	71.35	31.5	25.95	.9635	.9619	.9602
64	70.89	32.0	26.38	.9629	.9613	.9595
65	70.13	32.5	26.81	.9623	.9606	.9588
66	66.97	33.0	27.24	.9616	.9599	.9581
67	69.51	33.5	27.67	.9610	.9593	.9574
68	69.05	34.0	28.10	.9604	.9586	.9567
69	68.59	34.5	28.54	.9597	.9579	.9559
70	68.12	35.0	28.97	.9590	.9572	.9552
71	67.66	35.5	29.41	.9584	.9565	.9544
72	67.19	36.0	29.84	.9576	.9557	.9537
73	66.72	36.5	30.28	.9570	.9550	.9529
74	66.25	37.0	30.72	.9562	.9542	.9521
75	65.78	37.5	31.16	.9555	.9535	.9513
76	65.31	38.0	31.60	.9548	.9527	.9505
77	64.84	38.5	32.04	.9540	.9519	.9497
78	64.37	39.0	32.48	.9533	.9512	.9489
79	63.90	39.5	32.92	.9525	.9504	.9481
80	63.42	40.0	33.36	.9517	.9496	.9473
81	62.95	40.5	33.81	.9509	.9488	.9464
82	62.47	41.0	34.25	.9501	.9479	.9456
83	61.99	41.5	34.70	.9493	.9471	.9447

*The parts by volume of water and the parts by volume of ethyl alcohol do not add to unity (100) at any one proof reading, because of the shrinkage in volume which occurs when ethyl alcohol and water are mixed. The *parts by volume* of ethyl alcohol are the same as *percent by volume* of ethyl alcohol used to determine proof for tax purposes. Ethyl alcohol proof, by legal definition, is twice the percent by volume.

(continued)

Table 6.36: (continued)

U.S. PROOF degrees at 60°F	PARTS BY VOLUME* OF		WEIGHT % ETHYL ALCOHOL	SPECIFIC GRAVITY		
	WATER	ETHYL ALCOHOL		at 60°/60°F (15.56°/15.56°C)	at 68°/68°F (20°/20°C)	at 77°/77°F (25°/25°C)
84	61.52	42.0	35.15	.9485	.9463	.9439
85	61.04	42.5	35.60	.9477	.9454	.9430
86	60.56	43.0	36.05	.9469	.9446	.9421
87	60.08	43.5	36.50	.9460	.9437	.9412
88	59.59	44.0	36.96	.9452	.9428	.9403
89	59.11	44.5	37.41	.9443	.9419	.9394
90	58.63	45.0	37.86	.9434	.9410	.9385
91	58.14	45.5	38.32	.9426	.9402	.9376
92	57.66	46.0	38.78	.9417	.9292	.9366
93	57.17	46.5	39.24	.9408	.9383	.9357
94	56.68	47.0	39.70	.9399	.9374	.9348
95	56.19	47.5	40.16	.9389	.9364	.9338
96	55.70	48.0	40.62	.9380	.9355	.9328
97	55.21	48.5	41.09	.9371	.9345	.9319
98	54.72	49.0	41.55	.9361	.9336	.9309
99	54.22	49.5	42.02	.9352	.9326	.9299
100	53.73	50.0	42.49	.9342	.9316	.9289
101	53.24	50.5	42.96	.9332	.9306	.9279
102	52.74	51.0	43.43	.9322	.9296	.9269
103	52.25	51.5	43.90	.9312	.9286	.9258
104	51.75	52.0	44.37	.9302	.9276	.9248
105	51.25	52.5	44.85	.9292	.9266	.9238
106	50.75	53.0	45.33	.9282	.9256	.9228
107	50.26	53.5	45.80	.9272	.9245	.9217
108	49.76	54.0	46.28	.9262	.9235	.9207
109	49.26	54.5	46.76	.9252	.9225	.9196
110	48.76	55.0	47.24	.9241	.9214	.9185
111	48.25	55.5	47.73	.9230	.9204	.9175
112	47.75	56.0	48.21	.9220	.9193	.9164
113	47.25	56.5	48.70	.9210	.9182	.9153
114	46.75	57.0	49.19	.9199	.9171	.9142
115	46.24	57.5	49.68	.9188	.9161	.9131
116	45.74	58.0	50.17	.9177	.9150	.9120
117	45.23	58.5	50.66	.9166	.9139	.9109
118	44.72	59.0	51.15	.9156	.9128	.9098
119	44.22	59.5	51.65	.9144	.9116	.9087
120	43.71	60.0	52.15	.9133	.9105	.9076
121	43.20	60.5	52.65	.9122	.9094	.9064
122	42.69	61.0	53.15	.9111	.9083	.9053

*The parts by volume of water and the parts by volume of ethyl alcohol do not add to unity (100) at any one proof reading, because of the shrinkage in volume which occurs when ethyl alcohol and water are mixed. The *parts by volume* of ethyl alcohol are the same as *percent by volume* of ethyl alcohol used to determine proof for tax purposes. Ethyl alcohol proof, by legal definition, is twice the percent by volume.

(continued)

Table 6.36: (continued)

U.S. PROOF degrees at 60°F	PARTS BY VOLUME* OF		WEIGHT % ETHYL ALCOHOL	SPECIFIC GRAVITY		
	WATER	ETHYL ALCOHOL		at 60°/60°F (15.56°/15.56°C)	at 68°/68°F (20°/20°C)	at 77°/77°F (25°/25°C)
123	42.18	61.5	53.65	.9100	.9071	.9041
124	41.67	62.0	54.15	.9088	.9060	.9030
125	41.16	62.5	54.66	.9077	.9048	.9018
126	40.65	63.0	55.16	.9065	.9037	.9006
127	40.14	63.5	55.67	.9054	.9025	.8995
128	39.62	64.0	56.18	.9042	.9014	.8983
129	39.11	64.5	56.70	.9031	.9002	.8971
130	38.60	65.0	57.21	.9019	.8990	.8959
131	38.08	65.5	57.72	.9007	.8978	.8948
132	37.57	66.0	58.24	.8996	.8966	.8936
133	37.05	66.5	58.76	.8984	.8954	.8924
134	36.54	67.0	59.28	.8972	.8942	.8912
135	36.02	67.5	59.80	.8960	.8930	.8899
136	35.50	68.0	60.32	.8948	.8918	.8887
137	34.99	68.5	60.85	.8936	.8906	.8875
138	34.47	69.0	61.38	.8923	.8894	.8862
139	33.95	69.5	61.91	.8911	.8882	.8850
140	33.43	70.0	62.44	.8899	.8869	.8838
141	32.91	70.5	62.98	.8886	.8856	.8825
142	32.38	71.0	63.51	.8874	.8844	.8812
143	31.86	71.5	64.05	.8861	.8831	.8800
144	31.34	72.0	64.59	.8848	.8819	.8787
145	30.82	72.5	65.13	.8836	.8806	.8774
146	30.29	73.0	65.67	.8823	.8793	.8761
147	29.76	73.5	66.22	.8810	.8780	.8748
148	29.24	74.0	66.77	.8797	.8767	.8735
149	28.71	74.5	67.32	.8784	.8754	.8722
150	28.19	75.0	67.87	.8771	.8741	.8709
151	27.66	75.5	68.43	.8758	.8728	.8696
152	27.13	76.0	68.98	.8745	.8715	.8682
153	26.60	76.5	69.54	.8732	.8702	.8669
154	26.07	77.0	70.10	.8718	.8688	.8655
155	25.54	77.5	70.67	.8705	.8674	.8642
156	25.01	78.0	71.23	.8691	.8661	.8628
157	24.47	78.5	71.80	.8678	.8647	.8614
158	23.94	79.0	72.38	.8664	.8633	.8600
159	23.40	79.5	72.95	.8650	.8620	.8586
160	22.87	80.0	73.53	.8636	.8606	.8572
161	22.33	80.5	74.11	.8622	.8592	.8558

*The parts by volume of water and the parts by volume of ethyl alcohol do not add to unity (100) at any one proof reading, because of the shrinkage in volume which occurs when ethyl alcohol and water are mixed. The *parts by volume* of ethyl alcohol are the same as *percent by volume* of ethyl alcohol used to determine proof for tax purposes. Ethyl alcohol proof, by legal definition, is twice the percent by volume.

(continued)

Table 6.36: (continued)

U.S. PROOF degrees at 60°F	PARTS BY VOLUME* OF		WEIGHT % ETHYL ALCOHOL	SPECIFIC GRAVITY		
	WATER	ETHYL ALCOHOL		at 60°/60°F (15.56°/15.56°C)	at 68°/68°F (20°/20°C)	at 77°/77°F (25°/25°C)
162	21.80	81.0	74.69	.8608	.8577	.8544
163	21.26	81.5	75.27	.8594	.8563	.8530
164	20.72	82.0	75.86	.8580	.8549	.8516
165	20.18	82.5	76.45	.8566	.8535	.8501
166	19.64	83.0	77.04	.8552	.8520	.8487
167	19.10	83.5	77.64	.8537	.8506	.8472
168	18.55	84.0	78.23	.8522	.8491	.8458
169	18.01	84.5	78.84	.8508	.8476	.8443
170	17.46	85.0	79.44	.8493	.8461	.8428
171	16.92	85.5	80.05	.8478	.8446	.8413
172	16.37	86.0	80.66	.8462	.8431	.8398
173	15.82	86.5	81.28	.8447	.8416	.8382
174	15.27	87.0	81.90	.8432	.8400	.8367
175	14.72	87.5	82.52	.8416	.8385	.8351
176	14.16	88.0	83.14	.8401	.8369	.8335
177	13.61	88.5	83.78	.8385	.8353	.8319
178	13.05	89.0	84.41	.8369	.8337	.8303
179	12.49	89.5	85.05	.8353	.8321	.8287
180	11.93	90.0	85.69	.8336	.8305	.8271
181	11.37	90.5	86.34	.8320	.8288	.8254
182	10.80	91.0	86.99	.8303	.8271	.8237
183	10.24	91.5	87.65	.8286	.8254	.8220
184	9.67	92.0	88.31	.8268	.8237	.8203
185	9.09	92.5	88.98	.8251	.8219	.8185
186	8.52	93.0	89.65	.8233	.8201	.8167
187	7.94	93.5	90.34	.8215	.8183	.8149
188	7.36	94.0	91.02	.8196	.8164	.8130
189	6.77	94.5	91.72	.8178	.8146	.8111
190	6.18	95.0	92.42	.8158	.8126	.8092
191	5.59	95.5	93.14	.8138	.8107	.8072
192	4.99	96.0	93.85	.8118	.8087	.8052
193	4.39	96.5	94.58	.8098	.8066	.8032
194	3.78	97.0	95.32	.8077	.8045	.8011
195	3.17	97.5	96.07	.8056	.8024	.7990
196	2.55	98.0	96.82	.8033	.8002	.7968
197	1.93	98.5	97.60	.8010	.7978	.7944
198	1.29	99.0	98.38	.7987	.7955	.7921
199	.65	99.5	99.19	.7962	.7930	.7896
200	.00	100.0	100.00	.7936	.7905	.7871

U.S. Department of Commerce. STANDARD DENSITY AND VOLUMETRIC TABLES. CIRCULAR OF THE BUREAU OF STANDARDS NO. 19 (Washington: U.S. Government Printing Office, 1924) pp. 8, 9 & 18

U.S. Treasury Department, GAUGING MANUAL EMBRACING INSTRUCTIONS AND TABLES FOR DETERMINING THE QUANTITY OF DISTILLED SPIRITS BY PROOF AND WEIGHT (Washington: U.S. Government Printing Office, 1970).

Specific Gravity at 20°/20°C and 25°/25°C from Table 52.003, OFFICIAL METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS, Twelfth Edition, 1975.

*The parts by volume of water and the parts by volume of ethyl alcohol do not add to unity (100) at any one proof reading, because of the shrinkage in volume which occurs when ethyl alcohol and water are mixed. The *parts by volume* of ethyl alcohol are the same as *percent by volume* of ethyl alcohol used to determine proof for tax purposes. Ethyl alcohol proof, by legal definition, is twice the percent by volume.

Table 6.37: Specially Denatured Alcohols *(30)*

AUTHORIZED COMPOSITION:

	SDA 1-1[1]				SDA 1-2[2]				SDA 2B-1				Test Method
To every 100 gallons of alcohol add:													
Methyl Alcohol, gallons	4				4				—				
Denatonium Benzoate, N.F. avdp. oz.	1/8				—				—				
Methyl Isobutyl Ketone, gallons	—				1				—				
Benzene, gallons	—				—				0.5				
Rubber Hydrocarbon Solvent, gallons	—				—				—				
Toluene, gallons	—				—				—				
Metallic Sodium, pounds	—				—				—				
FORMULATION:	**190°**		**Anhydrous**		**190°**		**Anhydrous**		**190°**		**Anhydrous**		
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	
SPECIFICATIONS:													
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8144	0.8156	0.7934	0.7944	0.8142	0.8154	0.7934	0.7944	0.8154	0.8166	0.7939	0.7949	ASTM D-891
@ 20°C/20°C	0.8113	0.8124	0.7902	0.7912	0.8111	0.8122	0.7902	0.7912	0.8122	0.8134	0.7908	0.7918	
@ 25°C/25°C	0.8078	0.8090	0.7868	0.7879	0.8076	0.8088	0.7868	0.7879	0.8088	0.8100	0.7874	0.7884	
Acidity, wt/wt% as acetic acid	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	0.10	—	—	—	0.10	—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Typical				Organoleptic
TYPICAL PROPERTIES:													
Apparent proof at 60°F	190.4		199.9		190.5		199.9		189.9		199.7		I.R.S. Gauging Manual
Composition wt/wt%													
Ethyl Alcohol	88.95		96.14		88.12		95.22		91.92		99.45		
Methyl Alcohol	3.76		3.86		3.72		3.82		—		—		
Denatonium Benzoate	0.001		0.001		—		—		—		—		
Methyl Isobutyl Ketone	—		—		0.94		0.96		—		—		
Benzene	—		—		—		—		0.54		0.55		
Rubber Hydrocarbon Solvent	—		—		—		—		—		—		
Toluene	—		—		—		—		—		—		
Metallic sodium	—		—		—		—		—		—		
Water	7.29		—		7.22		—		7.54		—		
Coefficient of expansion													
Per 1°C	0.0010		0.0011		0.0010		0.0011		0.0010		0.0010		
Per 1°F	0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		
Flash point													
Tag closed cup													ASTM D-56
°C	13		12		14		11		18		12		
°F	56		53		58		52		64		54		
Tag open cup													ASTM D-1310
°C	23		22		18		16		18		16		
°F	73		71		65		60		65		60		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.788		6.612		6.788		6.611[3]		6.795		6.612		
Shipping containers													
Tank cars	√				√				√				
Tank trucks	√				√				√				
Drums	√				√				√				
Pails	√				√				√				

Comments:

1. Wood alcohol is an authorized denaturant for SDA 1 (27 CFR 212.16) but it is of no present commercial importance.
2. This formula must be used in a closed end continuous system unless it is shown that it is not practical to do so.
3. Determined by U.S.I.
4. 27 CFR 212.18 authorizes the use of one-half gallon rubber hydrocarbon solvent or toluene in lieu of benzene. Metallic sodium in excess of 33 pounds is also authorized. SDA 2C is only supplied in the anhydrous formulation. It must be used in a closed and continuous system unless it is shown that it is not practical to do so.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 2B-2[2]				SDA 2B-3[2]				SDA 2C-1[4]		SDA 3A				Test Method
To every 100 gallons of alcohol add:															
Methyl Alcohol, gallons	—				—				—		5				
Denatonium Benzoate, N.F. avdp. oz.	—				—				—		—				
Methyl Isobutyl Ketone, gallons	—				—				—		—				
Benzene, gallons	—				—				0.5		—				
Rubber Hydrocarbon Solvent, gallons	0.5				—				—		—				
Toluene, gallons	—				0.5				—		—				
Metallic Sodium, pounds	—				—				33		—				
FORMULATION:	**190°**		**Anhydrous**		**190°**		**Anhydrous**		**Anhydrous**		**190°**		**Anhydrous**		
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	
SPECIFICATIONS:															
Specific gravity @ 15.56°C 15.56°C (60°F 60°F)	0.8144	0.8156	0.7926	0.7936	0.8154	0.8166	0.7936	0.7946	0.8339	0.8372	0.8144	0.8156	0.7934	0.7944	ASTM D-891
@ 20°C 20°C	0.8113	0.8124	0.7895	0.7905	0.8122	0.8134	0.7905	0.7915	0.8308	0.8340	0.8113	0.8124	0.7902	0.7912	
@ 25°C 25°C	0.8078	0.8090	0.7862	0.7871	0.8088	0.8100	0.7871	0.7882	0.8274	0.8306	0.8078	0.8090	0.7869	0.7879	
Acidity, wt/wt% as acetic acid	—	0.0025	—	0.0025	—	0.0025	—	0.0025			—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams 100 ml	—	0.0025	—	0.0025	—	0.0025	—	0.0025			—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10			—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	0.10	—	—	—	0.10			—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Typical		Typical				Organoleptic
TYPICAL PROPERTIES:															
Apparent proof at 60°F	190.4		200.2		189.9		199.8		178.8		190.4		199.9		I.R.S. Gauging Manual
Composition wt/wt%															
Ethyl Alcohol	92.03		99.56		91.93		99.45				88.12		95.22		
Methyl Alcohol	—		—		—		—				4.65		4.78		
Denatonium Benzoate	—		—		—		—				—		—		
Methyl Isobutyl Ketone	—		—		—		—				—		—		
Benzene	—		—		—		—				—		—		
Rubber Hydrocarbon Solvent	0.42		0.44		—		—				—		—		
Toluene	—		—		0.53		0.55				—		—		
Metallic sodium	—		—		—		—				—		—		
Water	7.55		—		7.54		—				7.23		—		
Coefficient of expansion															
Per 1°C	0.0010		0.0010		0.0010		0.0011		0.0010		0.0010		0.0011		
Per 1°F	0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		
Flash point															
Tag closed cup															ASTM D-56
C	15		13		16		14				16		13		
F	59		56		61		57				60		55		
Tag open cup															ASTM D-1310
C	16		13		21		19		16		18		16		
F	60		55		69		66		60		65		60		
Pounds per gallon @ 60°F per 27 CFR 212.115	6.788[3]		6.606[3]		6.797[3]		6.613[3]		6.959		6.785		6.609		
Shipping containers															
Tank cars	√				√				No						
Tank trucks	√				√				No						
Drums	√				√				√						
Pails	√				√				No						

Comments

1. Wood alcohol is an authorized denaturant for SDA 1 (27 CFR 212.16) but it is of no present commercial importance.
2. This formula must be used in a closed end continuous system unless it is shown that it is not practical to do so.
3. Determined by U.S.I.
4. 27 CFR 212.18 authorizes the use of one-half gallon rubber hydrocarbon solvent or toluene in lieu of benzene. Metallic sodium in excess of 33 pounds is also authorized. SDA 2C is only supplied in the anhydrous formulation. It must be used in a closed and continuous system unless it is shown that it is not practical to do so.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 4[3]		SDA 6B				SDA 12A-1				Test Method
To every 100 gallons of alcohol add:											
Nicotine, solution[2], gallons	1		—				—				
Pyridine Bases, gallons	—		0.5				—				
Benzene, gallons	—		—				5				
Rubber Hydrocarbon Solvent, gallons	—		—				—				
Toluene, gallons	—		—				—				
Ethyl Ether, gallons	—		—				—				
FORMULATION:	**190°**		**190°**		**Anhydrous**		**190°**		**Anhydrous**		
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	
SPECIFICATIONS:											
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8181	0.8193	0.8160	0.8172	0.7939	0.7949	0.8183	0.8194	0.7972	0.7986	ASTM D-891
@ 20°C/20°C	0.8149	0.8161	0.8128	0.8140	0.7907	0.7918	0.8151	0.8162	0.7940	0.7955	
@ 25°C/25°C	0.8115	0.8126	0.8094	0.8105	0.7873	0.7884	0.8117	0.8128	0.7907	0.7921	
Acidity, wt/wt% as acetic acid	—	0.0025	← alkaline →				—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.01	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	Blue		—	30	—	30	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	—	—	0.20	—	—	—	0.10	ASTM D-1364
Odor	Typical		Typical				Typical				Organoleptic
TYPICAL PROPERTIES:											
Apparent proof at 60°F	188.5		189.6		199.7		188.4		198.3		I.R.S. Gauging Manual
Composition, wt/wt%											
Ethyl Alcohol	91.30		91.88		99.38		87.69		94.73		
Nicotine	0.024		—		—		—		—		
Methylene Blue	0.0003		—		—		—		—		
Pyridine Bases	—		0.59		0.62		—		—		
Benzene	—		—		—		5.12		5.27		
Rubber Hydrocarbon Solvent	—		—		—		—		—		
Toluene	—		—		—		—		—		
Ethyl Ether	—		—		—		—		—		
Water	8.68		7.53		—		7.19		—		
Coefficient of expansion											
Per 1°C	0.0010		0.0010		0.0010		0.0011		0.0011		
Per 1°F	0.0006		0.0006		0.0006		0.0006		0.0006		
Flash point											
Tag closed cup											ASTM D-56
C°	17		18		17		6		6		
F°	63		64		62		42		42		
Tag open cup											ASTM D-1310
C°	18		18		16		10		7		
F°	65		65		60		50		45		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.823		6.801		6.618		6.820		6.645		
Shipping containers											
Tank cars	✓		✓				✓				
Tank trucks	✓		✓				✓				
Drums	✓		✓				✓				
Pails	✓		✓				✓				

Comments:

1. SDA 3B, prepared by the addition of one gallon pine tar N.F. to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use, it is not discussed in this book.
2. Nicotine Solution Composition: Five gallons of an aqueous solution containing 40 percent nicotine and 3.6 av. ounces of methylene blue N.F., plus sufficient water to make 100 gallons.
3. Available in 190° formulation only.
4. Determined by U.S.I.
5. SDA 17, prepared by the addition of 0.05 gallon (6.4 fluid ounces) of bone oil (Dipple's Oil) to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 12A-3				SDA 13A				Test Method
To every 100 gallons of alcohol add:									
Nicotine, solution[2], gallons	—				—				
Pyridine Bases, gallons	—				—				
Benzene, gallons	—				—				
Rubber Hydrocarbon Solvent, gallons	—				—				
Toluene, gallons	5				—				
Ethyl Ether, gallons	—				10				
FORMULATION:	190°		Anhydrous		190°		Anhydrous		
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
SPECIFICATIONS:									
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8077	0.8189	0.7972	0.7986	0.8087	0.8100	0.7883	0.7895	ASTM D-891
@ 20°C/20°C	0.8146	0.8157	0.7940	0.7955	0.8056	0.8068	0.7857	0.7863	
@ 25°C/25°C	0.8111	0.8123	0.7907	0.7921	0.8022	0.8034	0.7816	0.7828	
Acidity, wt/wt% as acetic acid	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	0.10	—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Organoleptic
TYPICAL PROPERTIES:									
Apparent proof at 60°F	188.7		198.3		193.2		~200		I.R.S. Gauging Manual
Composition, wt/wt%									
Ethyl Alcohol	87.74		94.78		85.07		91.81		
Nicotine			—		—				
Methylene Blue			—		—				
Pyridine Bases			—		—				
Benzene			—		—				
Rubber Hydrocarbon Solvent			—		—				
Toluene	5.07		5.22		—				
Ethyl Ether			—		7.92		8.15		
Water	7.19		—		7.01		0.04		
Coefficient of expansion									
Per 1°C	0.0011		0.0011		0.0011		0.0012		
Per 1°F	0.0006		0.0006		0.0006		0.0006		
Flash point									
Tag closed cup									ASTM D-56
C°	11		9		−14		−16		
F°	52		49		6		4		
Tag open cup									ASTM D-1310
C°	18		16		−12		−12		
F°	65		60		10		10		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.815[4]		6.644[4]		6.740		6.572		
Shipping containers									
Tank cars	✓				✓				
Tank trucks	✓				✓				
Drums	✓				✓				
Pails	✓				✓				

Comments:

1. SDA 3B, prepared by the addition of one gallon pine tar N.F. to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use, it is not discussed in this book.
2. Nicotine Solution Composition: Five gallons of an aqueous solution containing 40 percent nicotine and 3.6 av. ounces of methylene blue N.F., plus sufficient water to make 100 gallons.
3. Available in 190° formulation only.
4. Determined by U.S.I.
5. SDA 17, prepared by the addition of 0.05 gallon (6.4 fluid ounces) of bone oil (Dipple's Oil) to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 20[3]		SDA 22[4]		SDA 23A				Test Method
To every 100 gallons of alcohol add:									
Chloroform, gallons	5		—		—				
Formaldehyde, Solution U.S.P., gallons	—		10		—				
Acetone, N.F., gallons	—		—		8				
Salicylic Acid, N.F., pounds	—		—		—				
Resorcin, U.S.P. pounds	—		—		—				
Bergamot Oil, N.F., gallons	—		—		—				
Methyl Isobutyl Ketone, gallons	—		—		—				
FORMULATION:	**Anhydrous**		**190°**		**190°**		**Anhydrous**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:									
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8265	0.8282	0.8444	0.8462	0.8144	0.8156	0.7939	0.7949	ASTM D-891
@ 20°C/20°C	0.8233	0.8251	0.8413	0.8431	0.8113	0.8124	0.7908	0.7918	
@ 25°C/25°C	0.8199	0.8216	0.8379	0.8398	0.8078	0.8090	0.7874	0.7884	
Acidity, wt/wt% as acetic acid	—	0.0050	—	0.010	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	0.10	—	—	—	—	—	0.10	ASTM D-1364
Odor	Typical		Typical		Typical				Organoleptic
TYPICAL PROPERTIES:									
Apparent proof at 60°F	183.7		172.6		190.4		199.7		I.R.S. Gauging Manual
Composition, wt/wt%									
Ethyl Alcohol	91.50		81.50		85.73		92.57		
Chloroform	8.50				—		—		
Formaldehyde	—		4.37		—		—		
Acetone	—		1.42-Methanol		7.24		7.43		
Salicylic Acid	—				—		—		
Resorcin	—				—		—		
Bergamot Oil	—				—		—		
Methyl Isobutyl Ketone	—				—		—		
Water	—		12.71		7.03		—		
Coefficient of expansion									
Per 1°C	0.0011		0.0010		0.0011		0.0011		
Per 1°F	0.0006		0.0006		0.0006		0.0006		
Flash point									
Tag closed cup									ASTM D-56
°C	13		18		6		4		
°F	56		65		43		40		
Tag open cup									ASTM D-1310
°C	13		17		16		16		
°F	55		62		60		60		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.886		7.037		6.788		6.621		
Shipping containers									
Tank cars	No		No		✓				
Tank trucks	No		No		✓				
Drums	✓		✓		✓				
Pails	✓		✓		✓				

Comments

1 SDA 18, prepared by the addition of 100 gallons of vinegar of not less than 90-grain strength or 150 gallons of vinegar of not less than 60-grain strength to every 100 gallons of alcohol is an authorized formula. It is not discussed in this book because of limited commercial importance.

2 SDA 19 prepared by the addition of 100 gallons of ethyl ether to every 100 gallons of alcohol is an authorized formula. Because of very limited use it is not discussed in this book.

3 Available in anhydrous formulation only

4 The 190° formulation is typically used

5 27 CFR 212.31 also authorizes the use of 1 gallon bay oil N.F., in lieu of the 1 gallon bergamot oil N.F.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 23F-1[5]				SDA 23H				Test Method
To every 100 gallons of alcohol add:									
Chloroform, gallons	—				—				
Formaldehyde, Solution U.S.P., gallons	—				—				
Acetone, N.F., gallons	—				8				
Salicylic Acid, N.F., pounds	3				—				
Resorcin, U.S.P. pounds	1				—				
Bergamot Oil, N.F., gallons	1				—				
Methyl Isobutyl Ketone, gallons	—				1.5				
FORMULATION:	**190°**		**Anhydrous**		**190°**		**Anhydrous**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:									
Specific gravity @ 15.56 C/15.56 C (60 F/60 F)	0.8193	0.8204	0.7964	0.7979	0.8140	0.8152	0.7942	0.7952	ASTM D-891
@ 20 C/20 C	0.8161	0.8172	0.7932	0.7948	0.8109	0.8120	0.7910	0.7920	
@ 25 C/25 C	0.8126	0.8138	0.7899	0.7914	0.8074	0.8086	0.7876	0.7886	
Acidity, wt/wt%, as acetic acid	0.10	0.20	0.10	0.20	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	N/A		N/A		—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	Pale Green		Pale Green		—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	0.40	—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Organoleptic
TYPICAL PROPERTIES:									
Apparent proof at 60 F	187.9		198.6		190.6		199.6		I.R.S. Gauging Manual
Composition, wt/wt%:									
Ethyl Alcohol	90.91		98.26		84.58		91.29		
Chloroform	—		—		—		—		
Formaldehyde	—		—		—		—		
Acetone	—		—		7.14		7.33		
Salicylic Acid	0.43		0.45		—		—		
Resorcin	0.14		0.15		—		—		
Bergamot Oil	1.06		1.09		—		—		
Methyl Isobutyl Ketone	—		—		1.35		1.38		
Water	7.46		—		6.93		—		
Coefficient of expansion									
Per 1 C	0.0010		0.0010		0.0011		0.0011		
Per 1 F	0.0006		0.0006		0.0006		0.0006		
Flash point									ASTM D-56
Tag closed cup									
C	16		13		6		2		
F	60		56		43		36		
Tag open cup									ASTM D-1310
C	18		18		10		2		
F	65		65		50		35		
Pounds per gallon @ 60 F per 27 CFR 212.115	6.808		6.627		6.785		6.617		
Shipping containers									
Tank cars	No								
Tank trucks	No								
Drums	No								
Pails	—Polyethylene lined								

Comments

1 SDA 18, prepared by the addition of 100 gallons of vinegar of not less than 90-grain strength or 150 gallons of vinegar of not less than 60-grain strength to every 100 gallons of alcohol is an authorized formula. It is not discussed in this book because of limited commercial importance.

2 SDA 19 prepared by the addition of 100 gallons of ethyl ether to every 100 gallons of alcohol is an authorized formula. Because of very limited use it is not discussed in this book.

3 Available in anhydrous formulation only.

4 The 190 formulation is typically used.

5 27 CFR 212.31 also authorizes the use of 1 gallon bay oil N.F. in lieu of the 1 gallon bergamot oil N.F.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 25-1[1]		SDA 25-2[1]		SDA 25A-1[1]		SDA 25A-2[1]		Test Method
To every 100 gallons of alcohol add:									
Iodine, U.S.P., pounds	20		20		20		20		
Potassium Iodide, U.S.P., pounds	15		—		15		—		
Sodium Iodide, U.S.P., pounds	—		15		—		15		
Water, pounds	—		—		15		15		
Rosemary Oil, N.F., gallons	—		—		—		—		
Camphor, U.S.P., pounds	—		—		—		—		
Clove Oil, U.S.P., gallons	—		—		—		—		
Lavender Oil, U.S.P., gallons	—		—		—		—		
Medicinal Soft Soap, U.S.P. pounds[2]	—		—		—		—		
FORMULATION:	190°		190°		190°		190°		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:									
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8491	0.8521	0.8494	0.8523	0.8535	0.8564	0.8541	0.8571	ASTM D-891
@ 20°C/20°C	0.8460	0.8490	0.8463	0.8492	0.8504	0.8533	0.8510	0.8539	
@ 25°C/25°C	0.8426	0.8456	0.8429	0.8459	0.8471	0.8500	0.8476	0.8506	
Acidity, wt/wt% as acetic acid	—	—	—	—	—	—	—	—	ASTM D-1613
Non-volatile matter, grams/100 ml	—	—	—	—	—	—	—	—	ASTM D-1353
Color, Pt-Co	Deep Red-Brown		Deep Red-Brown		Deep Red-Brown		Deep Red-Brown		ASTM D-1209
Water content, vol/vol %	—	—	—	—	—	—	—	—	ASTM D-1364
Odor	Typical		Typical		Typical		Typical		Organoleptic
TYPICAL PROPERTIES:									
Apparent proof at 60°F	169.1		168.9		166.1		165.7		I.R.S. Gauging Manual
Composition, wt/wt%									
Ethyl Alcohol	87.90		87.90		86.09		86.09		
Iodine	2.80		2.80		2.74		2.74		
Potassium Iodide	2.10		—		2.06		—		
Sodium Iodide	—		2.10		—		2.06		
Rosemary Oil	—		—		—		—		
Camphor	—		—		—		—		
Clove Oil	—		—		—		—		
Lavender Oil	—		—		—		—		
Soft Soap	—		—		—		—		
Water	7.20		7.20		9.11		9.11		
Coefficient of expansion									
Per 1°C	0.0010		0.0010		0.0010		0.0010		
Per 1°F	0.0006		0.0006		0.0006		0.0006		
Flash Point									
Tag closed cup									ASTM D-56
C°	16		16		16		16		
F°	60		60		60		60		
Tag open cup									ASTM D-1310
C°	18		18		18		18		
F°	65		65		65		65		
Pounds per gallon @ 60°F, per 27 CFR 212.115	7.080		7.083		7.119		7.117		
Shipping containers									
Tank cars	No		No		No		No		
Tank trucks	No		No		No		No		
Drums	50 gallon, polyethylene returnable drums only				50 gallon, polyethylene returnable drums only				
Pails	No		No		No		No		

Comments:

1. These SDA's typically supplied only in the 190° formulation
2. The requirements of this formula may be met by adding 66.5 pounds of U.S.P. quality soap concentrate containing 25 percent water to 100 gallons of alcohol and, after mixing, by adding thereto 33.5 pounds of water and mixing again.

(continued)

AUTHORIZED COMPOSITION:

	SDA 27				SDA 27A [1]		SDA 27B [1]		Test Method
To every 100 gallons of alcohol add:									
Iodine, U.S.P., pounds	—				—		—		
Potassium Iodide, U.S.P., pounds	—				—		—		
Sodium Iodide, U.S.P., pounds	—				—		—		
Water, pounds	—				—		—		
Rosemary Oil, N.F., gallons	1				—		—		
Camphor, U.S.P., pounds	30				35		—		
Clove Oil, U.S.P., gallons	—				1		—		
Lavender Oil, U.S.P., gallons	—				—		1		
Medicinal Soft Soap, U.S.P. pounds [2]	—				—		100		
FORMULATION:	**190°**		**Anhydrous**		**190°**		**190°**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:									
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8202	0.8240	0.7996	0.8020	0.8238	0.8263	0.8408	0.8448	ASTM D-891
@ 20°C/20°C	0.8170	0.8207	0.7964	0.7988	0.8207	0.8231	0.8377	0.8417	
@ 25°C/25°C	0.8136	0.8172	0.7930	0.7954	0.8172	0.8197	0.8343	0.8383	
Acidity, wt/wt% as acetic acid	—	0.005	—	0.010	—	0.030	—	—	ASTM D-1613
Non-volatile matter, grams/100 ml	N/A		N/A		N/A		—	—	ASTM D-1353
Color, Pt-Co	—	40	—	40	—	60			ASTM D-1209
Water content, vol/vol %	—	—	—	0.10	—	—	—	—	ASTM D-1364
Odor	Typical				Typical		Typical		Organoleptic
TYPICAL PROPERTIES:									
Apparent proof at 60°F	186.7		197.1		185.2		174.2		I.R.S. Gauging Manual
Composition, wt/wt%									
Ethyl Alcohol	87.58		94.62		86.83		79.79		
Iodine	—		—		—				
Potassium Iodide	—				—				
Sodium Iodide	—				—				
Rosemary Oil	1.06		1.08		—				
Camphor	4.18		4.30		4.84				
Clove Oil	—		—		1.21				
Lavender Oil	—		—		—		0.96		
Soft Soap	—		—		—		6.35		
Water	7.18		—		7.12		12.90		
Coefficient of expansion									
Per 1°C	0.0010		0.0010		0.0010		0.0010		
Per 1°F	0.0006		0.0006		0.0006		0.0006		
Flash Point									
Tag closed cup									ASTM D-56
C°	14		13		16		18		
F°	58		56		60		64		
Tag open cup									ASTM D-1310
C°	18		16		18		18		
F°	65		60		65		65		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.846		6.670		6.867		7.027		
Shipping containers									
Tank cars	No				No		No		
Tank trucks	No				No		No		
Drums	✓				X		✓		
Pails	✓				X		✓		

X = resin lined containers only.

Comments:

1 These SDA's typically supplied only in the 190° formulation.
2 The requirements of this formula may be met by adding 66.5 pounds of U.S.P. quality soap concentrate containing 25 percent water to 100 gallons of alcohol and, after mixing, by adding thereto 33.5 pounds of water and mixing again.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 28A[1]		SDA 29-3[2]				SDA 30		Test Method
To every 100 gallons of alcohol add:									
Gasoline, gallons	1		—				—		
Ethyl Acetate, gallons	—		1				—		
Methyl Alcohol, gallons	—		—				10		
Ethyl Ether, gallons	—		—				—		
FORMULATION:	**Anhydrous**		**190°**		**Anhydrous**		**190°**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:									
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.7923	0.7933	0.8160	0.8172	0.7944	0.7954	0.8132	0.8146	ASTM D-891
@ 20°C/20°C	0.7891	0.7901	0.8128	0.8140	0.7912	0.7922	0.8101	0.8115	
@ 25°C/25°C	0.7857	0.7867	0.8094	0.8105	0.7879	0.7889	0.8066	0.8080	
Acidity, wt/wt% as acetic acid	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	0.20	—	—	—	0.10	—	—	ASTM D-1364
Odor	Typical		Typical				Typical		Organoleptic
TYPICAL PROPERTIES:									
Apparent Proof at 60°F	>200		189.6		199.5		191.0		I.R.S. Gauging Manual
Composition wt/wt%									
Ethyl Alcohol	99.13		91.41		98.87		84.21		
Gasoline	0.87		—		—		—		
Ethyl Acetate	—		1.10		1.13		—		
Methyl Alcohol	—		—		—		8.89		
Ethyl Ether	—		—		—		—		
Water	—		7.49		—		6.90		
Coefficient of expansion									
Per 1°C	0.0011		0.0010		0.0011		0.0010		
Per 1°F	0.0006		0.0006		0.0006		0.0006		
Flash point									
Tag closed cup									ASTM D-56
C°	7		17		15		16		
F°	45		62		69		60		
Tag open cup									ASTM D-1310
C°	10		16		21		18		
F°	50		60		69		65		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.603		6.801[6]		6.621[6]		6.785		
Shipping containers									
Tank cars	√		√				√		
Tank trucks	√		√				√		
Drums	√		√				√		
Pails	√		√				√		

Comments:

1. This SDA typically supplied only in the anhydrous formulation.
2. This formulation, typically used for vinegar manufacture, is but one of many which is of commercial importance. Other denaturants may be approved by the ATF director, provided the proposed denaturant be not less than 6.8 pounds of solid, or 1 gallon of liquid to 100 gallons alcohol. This formula is restricted to processes in which the alcohol loses its identity by being converted to other chemicals.
3. SDA 31A, prepared by the addition of 100 pounds of glycerol, U.S.P. and 20 pounds of hard soap, N.F. to 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
4. SDA 33, prepared by the addition of 30 pounds of methyl violet or methyl violet U.S.P. to 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
5. SDA 35, prepared by the addition of 29.75 gallons of ethyl acetate having an ester content of 100 percent by weight or the equivalent thereof not to exceed 35 gallons of ethyl acetate with an ester content of not less than 85 percent by weight to 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed within this book.
6. Determined by U.S.I.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 30		SDA 32				SDA 35A				Test Method
To every 100 gallons of alcohol add:											
Gasoline, gallons	—		—				—				
Ethyl Acetate, gallons	—		—				4.25				
Methyl Alcohol, gallons	10		—				—				
Ethyl Ether, gallons	—		5				—				
FORMULATION:	**Anhydrous**		**190°**		**Anhydrous**		**190°**		**Anhydrous**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:											
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.7934	0.7944	0.8122	0.8134	0.7911	0.7921	0.8185	0.8196	0.7974	0.7989	ASTM D-891
@ 20°C/20°C	0.7902	0.7912	0.8091	0.8103	0.7879	0.7889	0.8153	0.8164	0.7942	0.7957	
@ 25°C/25°C	0.7868	0.7879	0.8056	0.8068	0.7845	0.7855	0.8119	0.8130	0.7909	0.7923	
Acidity, wt.wt% as acetic acid	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	0.20	—	—	—	0.20	—	—	—	0.10	ASTM D-1364
Odor	Typical		Typical				Typical				Organoleptic
TYPICAL PROPERTIES:											
Apparent Proof at 60°F	199.9		191.5		> 200		188.3		198.2		I.R.S. Gauging Manual
Composition wt/wt%											
Ethyl Alcohol	90.88		88.59		95.73		88.26		95.38		
Gasoline											
Ethyl Acetate							4.50		4.62		
Methyl Alcohol	9.12										
Ethyl Ether			4.13		4.24						
Water			7.28		0.03		7.24				
Coefficient of expansion											
Per 1°C	0.0011		0.0011		0.0011		0.0011		0.0011		
Per 1°F	0.0006		0.0006		0.0006		0.0006		0.0006		
Flash point											
Tag closed cup											ASTM D-56
C°	13		−4		−9		14		10		
F°	53		25		15		58		50		
Tag open cup											ASTM D-1310
C°	13		−4		−9		21		17		
F°	55		25		15		70		62		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.617		6.769		6.593		6.826		6.649		
Shipping containers											
Tank cars	✓		✓				✓				
Tank trucks	✓		✓				✓				
Drums	✓		✓				✓				
Pails	✓		✓				✓				

Comments:

1. This SDA typically supplied only in the anhydrous formulation.
2. This formulation, typically used for vinegar manufacture, is but one of many which is of commercial importance. Other denaturants may be approved by the ATF director, provided the proposed denaturant be not less than 6.8 pounds of solid, or 1 gallon of liquid to 100 gallons alcohol. This formula is restricted to processes in which the alcohol loses its identity by being converted to other chemicals.
3. SDA 31A, prepared by the addition of 100 pounds of glycerol, U.S.P. and 20 pounds of hard soap, N.F. to 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
4. SDA 33, prepared by the addition of 30 pounds of methyl violet or methyl violet U.S.P. to 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
5. SDA 35, prepared by the addition of 29.75 gallons of ethyl acetate having an ester content of 100 percent by weight or the equivalent thereof not to exceed 35 gallons of ethyl acetate with an ester content of not less than 85 percent by weight to 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed within this book.
6. Determined by U.S.I.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 36[1,2]		SDA 37[1]		TYPICAL SDA 38B		Test Method
To every 100 gallons of alcohol add:							
Ammonia, aqueous, 27 to 30 percent by weight, gallons	3		—				
Eucalyptol, U.S.P., fluid ounces	—		45				
Thymol N.F. avdp. ounce	—		30		Denaturant 10 lbs.		
Menthol, U.S.P., avdp. ounce	—		20				
Formaldehyde Solution, U.S.P., gallons	—		—				
Boric Acid,[4] U.S.P., pounds	—		—				
Chlorothymol, N.F., pounds	—		—				
FORMULATION:	190°		190°		190°	200°	
	Minimum	**Maximum**	**Minimum**	**Maximum**			
SPECIFICATIONS:							
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8189	0.8209	0.8162	0.8174	See Table 6.37		ASTM D-891
@ 20°C/20°C	0.8157	0.8177	0.8130	0.8142			
@ 25°C/25°C	0.8123	0.8143	0.8097	0.8108			
Acidity, wt/wt% as acetic acid	Alkaline		—	0.0030			ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.0025	N/A				ASTM D-1353
Color, Pt-Co	—	10	—	20			ASTM D-1209
Water content, vol/vol %	—	—	—	—			ASTM D-1364
Odor	Typical		Typical				Organoleptic
TYPICAL PROPERTIES:							
Apparent proof at 60°F	187.9		189.5		189.4	199.3	I.R.S. Gauging Manual
Composition, wt/wt%							
Ethyl Alcohol	89.46		91.64		91.08	98.51	
Ammonia	0.91						
Eucalyptol			0.40				
Thymol			0.27				
Menthol			0.18				
Formaldehyde			—				
Boric Acid			—				
Chlorothymol			—		Denaturant 1.45	1.49	
Water	9.63		7.51		7.47		
Coefficient of expansion							
Per 1°C	0.0011		0.0010		0.0010	0.0010	
Per 1°F	0.0006		0.0006		0.0006	0.0006	
Flash point							
Tag closed cup							ASTM D-56
C°	15		13				
F°	59		55				
Tag open cup							ASTM D-1310
C°	20		21				
F°	68		70				
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.837		6.794		6.804	6.622	
Shipping containers							
Tank cars	√		√		√		
Tank trucks	√		√		√		
Drums	√		√		√ & \		
Pails	√		√		√ & \		

Comments:

1. This SDA typically supplied only in the 190° proof formulation
2. Alternate denaturants include: 3 gallons of strong ammonia solution, U.S.P.; 17.5 pounds of caustic soda, liquid grade, containing 50 percent sodium hydroxide by weight; or 12.0 pounds of caustic soda, liquid grade containing 73 percent sodium hydroxide by weight to 100 gallons alcohol.
3. 27 CFR 212.51 also authorizes the use of 7 pounds of boric acid U.S.P. and a total of 3 pounds of any two or more denaturing materials listed under Formula No. 38-B.
4. The use of Polysorbate® 80 is an authorized replacement for boric acid.

(continued)

AUTHORIZED COMPOSITION:

	SDA 38C[1]		SDA 38D[1]		SDA 38F[1, 3]		Test Method
To every 100 gallons of alcohol add:							
Ammonia, aqueous, 27 to 30 percent by weight, gallons	—		—		—		
Eucalyptol, U.S.P., fluid ounces	—		—		—		
Thymol N.F. avdp. ounce	—		—		1⅓ lbs		
Menthol, U.S.P., avdp. ounce	10 lbs		2.5 lbs		1⅓ lbs		
Formaldehyde Solution, U.S.P., gallons	1.25		2.5		—		
Boric Acid,[4] U.S.P., pounds	—		—		6		
Chlorothymol, N.F., pounds	—		—		1⅓		
FORMULATION:	**190°**		**190°**		**190°**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:							
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.8202	0.8217	0.8231	0.8252	0.8194	0.8206	ASTM D-891
@ 20°C/20°C	0.8170	0.8185	0.8200	0.8221	0.8162	0.8174	
@ 25°C/25°C	0.8136	0.8151	0.8165	0.8187	0.8127	0.8140	
Acidity, wt/wt% as acetic acid	—	0.005	—	0.005	N/A		ASTM D-1613
Non-volatile matter, grams/100 ml	N/A		N/A		N/A		ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	—	—	—	ASTM D-1364
Odor	Typical		Typical		Typical		Organoleptic
TYPICAL PROPERTIES:							
Apparent proof at 60°F	187.3		185.5		187.8		I.R.S. Gauging Manual
Composition, wt/wt%							
Ethyl Alcohol	89.60		89.11		91.09		
Ammonia							
Eucalyptol					0.19		
Thymol	1.43		0.35				
Menthol	0.60		1.20				
Formaldehyde	0.19 Methanol		0.39 Methanol				
Boric Acid					0.87		
Chlorothymol					0.19		
Water	8.18		8.95		7.47		
Coefficient of expansion							
Per 1°C	0.0010		0.0010		0.0010		
Per 1°F	0.0006		0.0006		0.0006		
Flash point							
Tag closed cup							ASTM D-56
C°	17		17		16		
F°	62		63		61		
Tag open cup							ASTM D-1310
C°	19		22		19		
F°	67		71		66		
Pounds per gallon @ 60°F, per 27 CFR 212.115	6.832		6.863		6.828		
Shipping containers							
Tank cars	No		✓		✓		
Tank trucks	No		✓		✓		
Drums	X		X		✓ & X (depending on denaturants)		
Pails	X		X		✓ & X (depending on denaturants)		

X = resin lined containers

Comments:

1. This SDA typically supplied only in the 190° proof formulation
2. Alternate denaturants include: 3 gallons of strong ammonia solution, U.S.P.; 17.5 pounds of caustic soda, liquid grade, containing 50 percent sodium hydroxide by weight; or 12.0 pounds of caustic soda, liquid grade containing 73 percent sodium hydroxide by weight to 100 gallons alcohol.
3. 27 CFR 212.51 also authorizes the use of 7 pounds of boric acid U.S.P. and a total of 3 pounds of any two or more denaturing materials listed under Formula No. 38-B.
4. The use of Polysorbate® 80 is an authorized replacement for boric acid.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:	SDA 39B				SDA 39C				SDA 40-1				Test Method
To every 100 gallons of alcohol add:													
Diethyl Phthalate, gallons	2.5				1				—				
tert-Butyl Alcohol, gallons	⅛				—				⅛				
Brucine Alkaloid, avdp ounces	—				—				1½				
Brucine Sulfate N.F. IX, avdp ozs.	—				—				—				
Sucrose Octaacetate, pounds	—				—				—				
Denatonium Benzoate, N.F., avdp ounces	—				—				—				
FORMULATION:	**190°**		**Anhydrous**		**190°**		**Anhydrous**		**190°**		**Anhydrous**		
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	
SPECIFICATIONS:													
Specific gravity													
@ 15.56°C/15.56°C(60°F/60°F)	0.8228	0.8238	0.8028	0.8038	0.8182	0.8192	0.7964	0.7979	0.8150	0.8164	0.7934	0.7944	ASTM D-891
@ 20°C/20°C	0.8196	0.8207	0.7997	0.8007	0.8149	0.8161	0.7932	0.7948	0.8122	0.8132	0.7902	0.7912	
@ 25°C/25°C	0.8162	0.8172	0.7963	0.7972	0.8155	0.8126	0.7899	0.7914	0.8088	0.8098	0.7868	0.7879	
Acidity, wt/wt% as acetic acid	—	0.0050	—	0.0050	—	0.0050	—	0.0050	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	N/A		N/A		N/A		N/A		—	0.020	—	0.020	ASTM D-1353
Color, Pt-Co	—	20	—	20	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	0.10	—	—	—	0.10	—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Typical				Organoleptic
TYPICAL PROPERTIES:													
Apparent Proof at 60°F	186.0		196.0		188.5		198.6		190.0		199.9		I.R.S. Gauging Manual
Composition wt/wt%													
Ethyl Alcohol	89.25		96.47		91.17		98.61		92.30		99.87		
Diethyl Phthalate	3.32		3.41		1.36		1.39		—		—		
tert-Butyl Alcohol	0.12		0.12		—		—		0.12		0.12		
Brucine Alkaloid	—		—		—		—		0.014		0.014		
Brucine Sulfate	—		—		—		—		—		—		
Sucrose Octaacetate	—		—		—		—		—		—		
Denatonium Benzoate	—		—		—		—		—		—		
Water	7.31		—		7.47		—		7.57		—		
Coefficient of expansion													
Per 1°C	0.0010		0.0011		0.0010		0.0011		0.0010		0.0011		
Per 1°F	0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		
Flash point													
Tag closed cup													ASTM D-56
C°	14		13		16		13		16		13		
F°	58		55		60		55		61		56		
Tag open cup													ASTM D-1310
C°	18		16		18		16		18		16		
F°	65		60		65		60		65		60		
Pounds per gallon													
@ 60°F, per 27 CFR 212.115	6.857		6.677		6.819		6.642		6.795		6.611		
Shipping containers													
Tank cars	✓				✓				✓				
Tank trucks	✓				✓				✓				
Drums	✓				✓				✓				
Pails	✓				✓				✓				

Comments:

1. SDA 39, prepared by the addition of 9 pounds of sodium salicylate or salicylic acid U.S.P., 1.25 gallons fluid extract of quassia, N.F. VII and ⅛ gallon of tert-butyl alcohol to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
2. SDA 39A, prepared by the addition of 60 avdp. ounces of any of the following alkaloids or salts together with ⅛ gallon of tert-butyl alcohol: quinine N.F., quinine bisulfate N.F., quinine hydrochloride, U.S.P. cinchonidine, cinchonidine sulfate, N.F. IX to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
3. SDA 39D, prepared by the addition of one gallon bay oil N.F. and either 50 avdp ounces of quinine sulfate, U.S.P., 50 avdp ounces of quinine bisulfate, N.F., or 200 avdp. ounces sodium salicylate, U.S.P. to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
4. Determined by U.S.I.
5. This formula shall be used only in the manufacture of products which will be packaged in pressurized containers in which the liquid contents are in intimate contact with the propellant and from which the contents are not easily removable in liquid form.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:	SDA 40-2				SDA 40A				SDA 40B				SDA 40C[5]				Test Method
To every 100 gallons of alcohol add:																	
Diethyl Phthalate, gallons	—				—				—				—				
tert-Butyl Alcohol, gallons	1/8				1/8				1/8				3				
Brucine Alkaloid, avdp ounces	—				—				—				—				
Brucine Sulfate N.F. IX, avdp ozs.	1 1/2				—				—				—				
Sucrose Octaacetate, pounds	—				1				—				—				
Denatonium Benzoate, N.F., avdp ounces	—				—				1/16				—				
FORMULATION:	190°		Anhydrous		190°		Anhydrous		190°		Anhydrous		190°		Anhydrous		
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	
SPECIFICATIONS:																	
Specific gravity																	
@ 15.56°C/15.56°C(60°F/60°F)	0.8154	0.8164	0.7934	0.7944	0.8158	0.8170	0.7939	0.7949	0.8152	0.8164	0.7934	0.7944	0.8148	0.8160	0.7829	0.7939	ASTM D-891
@ 20°C/20°C	0.8122	0.8132	0.7902	0.7912	0.8126	0.8138	0.7908	0.7918	0.8120	0.8132	0.7902	0.7912	0.8116	0.8128	0.7898	0.7908	
@ 25°C/25°C	0.8088	0.8098	0.7868	0.7879	0.8192	0.8104	0.7874	0.7884	0.8086	0.8098	0.7868	0.7879	0.8082	0.8094	0.7864	0.7874	
Acidity, wt/wt% as acetic acid	—	0.0050	—	0.0050	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1613
Non-volatile matter, grams/100 ml	—	0.020	—	0.020	—	0.16	—	0.16	—	0.0025	—	0.0025	—	0.0025	—	0.0025	ASTM D-1353
Color, Pt-Co	—	10	—	10	—	10	—	10	—	10	—	10	—	10	—	10	ASTM D-1209
Water content, vol/vol %	—	—	—	0.10	—	—	—	0.10	—	—	—	0.10	—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Typical				Typical				Organoleptic
TYPICAL PROPERTIES:																	
Apparent Proof at 60°F	190.0		199.9		189.7		199.7		190.0		199.9		190.2		200.1		I.R.S. Gauging Manual
Composition wt/wt%																	
Ethyl Alcohol	92.30		99.87		92.18		99.73		92.31		99.88		89.84		97.13		
Diethyl Phthalate	—		—		—		—		—		—		—		—		
tert-Butyl Alcohol	0.12		0.12		0.12		0.12		0.12		0.12		2.79		2.87		
Brucine Alkaloid	—		—		—				—		—		—		—		
Brucine Sulfate	0.014		0.014		—				—		—		—		—		
Sucrose Octaacetate	—		—		0.15		0.15		—		—		—		—		
Denatonium Benzoate	—		—		—				0.0006		0.0006		—		—		
Water	7.57		—		7.55		—		7.57		—		7.37		—		
Coefficient of expansion																	
Per 1°C	0.0010		0.0010		0.0011		0.0011		0.0010		0.0011		0.0010		0.0011		
Per 1°F	0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		0.0006		
Flash point																	
Tag closed cup																	ASTM D-56
C°	16		13		16		12		17		13		16		13		
F°	61		56		60		53		63		56		61		55		
Tag open cup																	ASTM D-1310
C°	18		16		18		17		18		16		18		16		
F°	65		60		65		62		65		60		65		60		
Pounds per gallon																	
@ 60°F, per 27 CFR 212.115	6.795[4]		6.611[4]		6.798		6.613		6.794		6.610		6.788		6.609		
Shipping containers																	
Tank cars	✓				✓				✓				✓				
Tank trucks	✓				✓				✓				✓				
Drums	✓				✓				✓				✓				
Pails	✓				✓				✓				✓				

Comments:

1. SDA 39, prepared by the addition of 9 pounds of sodium salicylate or salicylic acid U.S.P., 1.25 gallons fluid extract of quassia, N.F. VII and 1/8 gallon of tert-butyl alcohol to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
2. SDA 39A, prepared by the addition of 60 avdp. ounces of any of the following alkaloids or salts together with 1/8 gallon of tert-butyl alcohol: quinine N.F., quinine bisulfate N.F., quinine hydrochloride, U.S.P. cinchonidine, cinchonidine sulfate, N.F. IX to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
3. SDA 39D, prepared by the addition of one gallon bay oil N.F. and either 50 avdp ounces of quinine sulfate, U.S.P., 50 avdp ounces of quinine bisulfate, N.F., or 200 avdp. ounces sodium salicylate, U.S.P. to every 100 gallons alcohol, is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
4. Determined by U.S.I.
5. This formula shall be used only in the manufacture of products which will be packaged in pressurized containers in which the liquid contents are in intimate contact with the propellant and from which the contents are not easily removable in liquid form.

(continued)

Table 6.37: (continued)

AUTHORIZED COMPOSITION:

	SDA 45				SDA 46[4]				Test Method
To every 100 gallons of alcohol add:									
Refined Shellac, pounds	300				—				
Phenol, U.S.P., fl. ounces	—				25				
Methyl Salicylate, U.S.P., fl. ounces	—				4				
FORMULATION:	**190°**		**Anhydrous**		**190°**		**Anhydrous**		
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
SPECIFICATIONS:									
Specific gravity @ 15.56°C/15.56°C (60°F/60°F)	0.9036	0.9071	0.8868	0.8905	0.8166	0.8178	0.7946	0.7954	ASTM D-891
@ 20°C/20°C	0.9008	0.9043	0.8838	0.8875	0.8134	0.8146	0.7915	0.7925	
@ 25°C/25°C	0.8977	0.9012	0.8806	0.8844	0.8100	0.8112	0.7882	0.7892	
Acidity as acetic acid	N/A		N/A		—	0.02	—	0.02	ASTM D-1613
Non-volatile matter, grams/100 ml	N/A		N/A		N/A		N/A		ASTM D-1353
Color, Pt-Co	N/A		N/A		—	10	—	10	ASTM D-1209
Water content, vol/vol %	N/A		N/A		—	—	—	0.10	ASTM D-1364
Odor	Typical				Typical				Organoleptic
TYPICAL PROPERTIES:									
Apparent Proof at 60°F	127.0		141.0		189.3		199.4		I.R.S. Gauging Manual
Composition, wt/wt %									
Ethyl Alcohol	64.11		68.78		92.18		99.73		
Shellac	30.63		31.22		—		—		
Phenol			—		0.23		0.23		
Methyl Salicylate			—		0.04		0.04		
Water	5.26		—		7.55		—		
Coefficient of expansion									
Per 1°C	0.0009		0.0009		0.0011		0.0010		
Per 1°F	0.0005		0.0005		0.0006		0.0006		
Flash point									
Tag closed cup									ASTM D-56
C°					17		12		
F°					63		54		
Tag open cup									ASTM D-1310
C°	21		18		21		16		
F°	70		65		70		60		
Pounds per gallon @ 60°F, per 27 CFR 212.115	7.545		7.403		6.805		6.621		
Shipping containers									
Tank cars	No				No				
Tank trucks	No				No				
Drums	50 gallon open load drums				X				
Pails	No				X				

Comments:

1. SDA 42, prepared by addition of (1) 80 grams of potassium iodide, U.S.P. and 109 grams of red mercuric iodide, N.F.; (2) 95 grams thimerosal, N.F.; or (3) 76 grams of any of the following: phenyl mercuric nitrate, N.F.; phenyl mercuric chloride, N.F. IX or phenyl mercuric benzoate, to every 100 gallons alcohol is an ATF authorized formulation. Because of very limited use it is not discussed in this book.
2. SDA 44, prepared by the addition of 10 gallons of n-butyl alcohol is an ATF authorized formulation. Because of very limited use it is not discussed in this book. Specific information may be obtained by contacting any U.S.I. sales office.
3. This formula may be used only by institutions and organizations which are of a semipublic character and engaged in charitable work.
4. This formula may be used only by organizations or institutions which are of a semipublic character and engaged in charitable work.

Table 6.38: Authorized Denaturants for SDA 38B *(30)*

The properties of SDA 38B are as diverse as are the denaturants used in this formula and the products formulated with it.

The authorized composition of SDA 38B requires that 10 pounds of any one, or a total of 10 pounds of two or more, of the oils and substances listed below are to be added to 100 gallons of alcohol. The authorized denaturants include:

Anethole, U.S.P.
Anise oil, U.S.P.
Bay oil (myrcia oil), N.F.
Benzaldehyde, N.F.
Bergamot oil, N.F.
Bitter Almond oil, N.F.
Camphor, U.S.P.
Cedar leaf oil, U.S.P. XIII
Chlorothymol, N.F.
Cinnamic Aldehyde, N.F. IX
Cinnamon oil (Cassia oil), U.S.P.
Citronella oil, Natural
Clove oil, U.S.P.
Coal tar, U.S.P.
Eucalyptol, U.S.P.
Eucalyptus oil, N.F.
Eugenol, U.S.P.
Guaiacol, N.F.
Lavender oil, N.F.
Menthol, U.S.P.
Mustard oil, volatile (allyl isothiocyanate) U.S.P.
Peppermint oil, U.S.P.
Phenol, U.S.P.
Phenyl salicylate (Salol), N.F.
Pine oil, N.F.
Pine needle oil, dwarf, N.F.
Rosemary oil, N.F.
Spearmint oil, N.F.
Spearmint oil, terpeneless
Spike lavender oil, natural
Storax, U.S.P.
Thyme oil, N.F.
Thymol, N.F.
Tolu balsam, U.S.P.
Turpentine oil, N.F.
Wintergreen oil (methyl salicylate) U.S.P.

Because of the virtually infinite number of authorized denaturants and denaturant combinations, only a typical set of properties for SDA 38B have been listed

Table 6.39: Denaturants Authorized for Completely Denatured Alcohol (CDA) and Specially Denatured Alcohol (SDA) *(30)*

DENATURANT	USED IN
Acetaldehyde	S.D.A. 29
Acetone N.F.	S.D.A. 23A; 23-H
Acetaldol	C.D.A. 18
Almond oil, bitter N.F.	S.D.A. 38-B
Ammonia, aqueous	S.D.A. 36
Anethole U.S.P.	S.D.A. 38-B
Anise oil U.S.P.	S.D.A. 38-B
Bay oil (myrcia oil) N.F.	S.D.A. 23-F; 38-B; 39-D
Benzaldehyde N.F.	S.D.A. 38-B
Benzene	S.D.A. 2-B; 2-C; 12-A
Bergamot oil N.F.	S.D.A. 23-F; 38-B
Bone oil (Dipple's oil)	S.D.A. 17
Boric acid U.S.P.	S.D.A. 38-F
Brucine alkaloid	S.D.A. 40
Brucine sulfate N.F. IX	S.D.A. 40
n-Butyl alcohol	S.D.A. 44
tert-Butyl alcohol	S.D.A. 39, 39-A; 39-B; 40; 40-A; 40-B; 40-C
Camphor U.S.P.	S.D.A. 27; 27-A; 38-B
Caustic soda, liquid	S.D.A. 36
Cedar leaf oil U.S.P. XIII	S.D.A. 38-B
Chloroform	S.D.A. 20
Chlorothymol N.F.	S.D.A. 38-B; 38-F
Cinchonidine	S.D.A. 39-A
Cinchonidine sulfate N.F. IX	S.D.A. 39-A
Cinnamic aldehyde (cinnamaldehyde) N.F. IX	S.D.A. 38-B
Cinnamon oil (cassia oil) U.S.P.	S.D.A. 38-B
Citronella oil, natural	S.D.A. 38-B
Clove oil U.S.P.	S.D.A. 27-A; 38-B
Coal tar U.S.P.	S.D.A. 38-B
Denatonium benzoate N.F. (Bitrex)	S.D.A. 1; 40-B
Diethyl phthalate	S.D.A. 39-B; 39-C
Ethyl acetate	S.D.A. 29; 35; 35-A
Ethyl ether	S.D.A. 13-A; 19; 32
Eucalyptol U.S.P.	S.D.A. 37; 38-B
Eucalyptus oil N.F.	S.D.A. 38-B
Eugenol U.S.P.	S.D.A. 38-B
Formaldehyde solution U.S.P.	S.D.A. 22; 38-C; 38-D
Gasoline	C.D.A. 18; 19; 20; S.D.A. 28-A
Glycerol U.S.P.	S.D.A. 31-A
Guaiacol N.F.	S.D.A. 38-B
Iodine U.S.P.	S.D.A. 25; 25-A
Kerosene	C.D.A. 18; 19; 20
Lavender oil U.S.P.	S.D.A. 27-B; 38-B
Menthol U.S.P.	S.D.A. 37; 38-B; 38-C; 38-D; 38-F
Mercuric iodide, red N.F.	S.D.A. 42
Methyl alcohol	S.D.A. 3-A; 30
Methylene blue N.F.	S.D.A. 4
Methyl isobutyl ketone	C.D.A. 18; 19; S.D.A. 1; S.D.A. 23-H
Methyl normal-butyl ketone	C.D.A. 18; 19; S.D.A. 1
Methyl violet (methylrosaniline chloride)	S.D.A. 33
Methyl violet (methylrosaniline chloride) U.S.P.	S.D.A. 33
Mustard oil, volatile (allyl isothiocyanate) U.S.P. XII	S.D.A. 38-B
Nicotine solution	S.D.A. 4
Peppermint oil U.S.P.	S.D.A. 38-B
Phenol U.S.P.	S.D.A. 38-B; 46
Phenyl mercuric benzoate	S.D.A. 42
Phenyl mercuric chloride N.F. IX	S.D.A. 42
Phenyl mercuric nitrate N.F.	S.D.A. 42
Phenyl salicylate (salol) N.F.	S.D.A. 38-B
Pine needle oil, dwarf N.F.	S.D.A. 38-B
Pine oil N.F.	S.D.A. 38-B
Pine tar N.F.	S.D.A. 3-B
Polysorbate 80 U.S.P.	S.D.A. 38-F
Potassium iodide U.S.P.	S.D.A. 25; 25-A; 42
Pyridine bases	S.D.A. 6-B
Pyronate	C.D.A. 18
Quassia, fluid extract of N.F. VII	S.D.A. 39
Quassin	S.D.A. 40
Quinine N.F.	S.D.A. 39-A
Quinine bisulfate N.F.	S.D.A. 39-A; 39-D
Quinine hydrochloride U.S.P.	S.D.A. 39-A
Quinine sulfate U.S.P.	S.D.A. 39-D
Resorcin U.S.P.	S.D.A. 23-F
Rosemary oil N.F.	S.D.A. 27; 38-B
Rubber hydrocarbon solvent	S.D.A. 2-B; 2-C
Salicylic acid U.S.P.	S.D.A. 23-F; 39
Shellac (refined)	S.D.A. 45
Soap, hard N.F.	S.D.A. 31-A
Soap, medicinal soft U.S.P.	S.D.A. 27-B
Sodium iodide U.S.P.	S.D.A. 25; 25-A
Sodium, metallic	S.D.A. 2-C
Sodium salicylate U.S.P.	S.D.A. 39; 39-D
Spearmint oil N.F.	S.D.A. 38-B
Spearmint oil, terpeneless	S.D.A. 38-B
Spike lavender oil, natural	S.D.A. 38-B
Storax U.S.P.	S.D.A. 38-B
Sucrose octa-acetate	S.D.A. 40-A
Thimerosal, N.F.	S.D.A. 42
Thyme oil N.F.	S.D.A. 38-B
Thymol N.F.	S.D.A. 37; 38-B; 38-F
Tolu balsam U.S.P.	S.D.A. 38-B
Toluene	S.D.A. 2-B; 2-C; 12-A
Turpentine oil N.F.	S.D.A. 38-B
Vinegar	S.D.A. 18
Wintergreen (Methyl salicylate) U.S.P.	S.D.A. 38-B; 46

Primary Denaturants Authorized for Denatured Spirits—Title 27 Code of Federal Regulations 212.110

Table 6.40: Uses of Specially Denatured Alcohol* *(30)*

PRODUCT OR PROCESS	CODE NO.	FORMULAS AUTHORIZED
Acetaldehyde	.551	1, 2-B, 29
Acetic acid	.512	1, 2-B, 29, 35-A
Adhesives and binders	.036	1, 3-A, 12-A, 23-A, 30
Aldehydes, miscellaneous	.552	1, 2-B, 29
Alkaloids (processing)	.344	1, 2-B, 2-C, 3-A, 12-A, 13-A, 17, 23-A, 30, 32, 35-A
Animal feed supplement	.910	35-A
Antibiotics (processing)	.343	1, 2-B, 3-A, 12-A, 13-A, 23-A, 30, 32, 35-A
Antifreeze, proprietary	.760	1
Antiseptic, bathing solution (restricted)	.220	46
Antiseptic solutions, U.S.P. or N.F.	.244	23-A, 37, 38-B, 38-F
Bath preparations	.142	1, 3-A, 3-B, 23-A, 30, 36, 38-B, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Bay rum	.112	23-A, 37, 38-B, 39, 39-B, 39-D, 40, 40-A, 40-B, 40-C
Biocides, miscellaneous	.410	1, 3-A, 3-B, 23-A, 23-H, 27-A, 27-B, 30, 37, 38-B, 39B, 40, 40-A, 40-B, 40-C
Blood and blood products (processing)	.345	1, 3-A. 12-A, 13-A, 23-A, 30
Brake fluids	.720	1, 3-A
Candy glazes	.015	13-A, 23-A, 35, 35-A, 45
Cellulose coatings	.011	1, 23-A, 30
Cellulose compounds (dehydration)	.311	1, 2-B, 3-A, 32
Cellulose intermediates	.034	1, 3-A, 12-A, 13-A, 19, 23-A, 32
Chemicals (miscellaneous)	.579	1, 2-B, 2-C, 3-A, 6-B, 12-A, 13-A, 17, 20, 29, 30, 32, 36
Cleaning solutions	.450	1, 3-A, 23-A, 23-H, 30, 36, 39-B, 40, 40A, 40-B, 40-C
Coatings, miscellaneous	.016	1, 23-A
Collodions, industrial	.034	1, 3-A, 12-A, 13-A, 19, 23-A, 32
Collodions, U.S.P. or N.F.	.241	13-A, 19, 32
Colognes	.122	38-B, 39, 39-A, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Crude drugs (processing)	.341	1, 2-B, 3-A, 23-A, 30
Cutting oils	.730	1, 3-A, 12-A
Dehydration products, miscellaneous	.315	1, 2-B, 3-A
Dentifrices	.131	31-A, 37, 38-B, 38-C, 38-D
Deodorants (body)	.114	23-A, 38-B, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Detergents, household	.450	1, 3-A, 23-A, 23-H, 30, 36, 39-B, 40, 40-A, 40-B, 40-C
Detergents, industrial	.440	1, 3-A, 23-A, 30
Detonators	.574	1, 6-B
Disinfectants	.410	1, 3-A, 3-B, 23-A, 23-H, 27-A, 27-B, 30, 37, 38-B, 39-B, 40, 40-A, 40-B, 40-C
Drugs and medicinal chemicals	.575	1, 2-B, 2-C, 3-A, 6-B, 12-A, 13-A, 17, 29, 30, 32
Drugs, miscellaneous (processing)	.349	1, 2-B, 3-A, 13-A, 23-A, 30, 35-A, 38-B
Duplicating fluids	.485	1, 3-A, 30
Dyes and intermediates	.540	1, 2-B, 2-C, 3-A, 12-A, 29, 36
Dyes and intermediates (processing)	.351	1, 2-B, 3-A, 12-A
Dye solutions, miscellaneous	.482	1, 3-A, 23-A, 30, 39-C, 40, 40-A, 40-B, 40-C
Embalming fluids, etc.	.420	1, 3-A, 22, 23-A
Esters, ethyl (miscellaneous)	.523	1, 2-B, 2-C, 3-A, 6-B, 12-A, 13-A, 17, 29, 32, 35-A
Ether, ethyl	.561	1, 2-B, 13-A, 29, 32
Ethers, miscellaneous	.562	1, 2-B, 13-A, 29, 32
Ethyl acetate	.521	1, 2-B, 29, 35-A
Ethylamines	.530	1, 2-B, 2-C, 3-A, 12-A, 29, 36
Ethyl chloride	.522	1, 2-B, 29, 32
Ethylene dibromide	.571	1, 2-B, 29, 32
Ethylene gas	.572	1, 2-B, 29, 32
Explosives	.033	1, 2-B, 3-A
External pharmaceuticals (not U.S.P. or N.F.)	.210	23-A, 23-F, 23-H, 27-A, 27-B, 36, 37, 38-B, 38-F, 39-B, 40, 40-A, 40-B, 40-C
External pharmaceuticals, miscellaneous (U.S.P. or N.F.)	.249	23-A, 25, 25-A, 38-B
Fluid uses, miscellaneous	.750	1, 3-A, 23-A, 30
Food products, miscellaneous (processing)	.332	1, 2-B, 3-A, 13-A, 23-A, 30, 32, 35-A
Fuel uses, miscellaneous	.630	1, 3-A, 28-A
Fuels, airplane and supplementary	.612	1, 3-A, 28-A
Fuels, automobile and supplementary	.611	1, 3-A, 28-A
Fuels, proprietary heating	.620	1, 3-A, 28-A
Fuels, rocket and jet	.613	1, 3-A, 28-A
Fungicides	.410	1, 3-A, 3-B, 23-A, 23-H, 27-A, 27-B, 30, 37, 38-B, 39-B, 40, 40-A, 40-B, 40-C
Glandular products (processing)	.342	1, 2-B, 3-A, 12-A, 13-A, 23-A, 30, 32, 35-A
Hair and scalp preparations	.111	3-B, 23-A, 23-F, 23-H, 37, 38-B, 39, 39-A, 39-B, 39-C, 39-D, 40, 40-A, 40-B, 40-C
Hormones (processing)	.342	1, 2-B, 3-A, 12-A, 13-A, 23-A, 30, 32, 35-A

*Other products or processes may be authorized by the Director of the Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury, Washington, D.C. Uses of Specially Denatured Alcohol—27 CFR 212.105

(continued)

Table 6.40: (continued)

PRODUCT OR PROCESS	CODE NO.	FORMULAS AUTHORIZED
Incense	.470	3-A, 22, 37, 38-B, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Inks	.052	1, 3-A, 13-A, 23-A, 30, 32, 33
Inks (including meat branding)	.052	23-A, 32
Insecticides	.410	1, 3-A, 3-B, 23-A, 23-H, 27-A, 27-B, 30, 37, 38-B, 39-B, 40, 40-A, 40-B, 40-C
Iodine solutions (including U.S.P. and N.F. tinctures)	.230	25, 25-A
Laboratory reagents (for sale)	.810	3-A, 30
Laboratory uses	.810	3-A, 30
Lacquer thinners	.042	1, 23-A
Liniments (U.S.P. or N.F.)	.243	27, 27-B, 38-B
Lotions and creams (body, face, and hand)	.113	23-A, 23-H, 31-A, 37, 38-B, 39, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Medicinal chemicals (processing)	.344	1, 2-B, 2-C, 3-A, 12-A, 13-A, 17, 23-A, 30, 32, 35-A
Miscellaneous chemicals (processing)	.358	1, 2-B, 2-C, 3-A, 12-A, 13-A, 17, 23-A, 30, 35-A
Miscellaneous products (processing)	.359	1, 2-B, 2-C, 3-A, 12-A, 13-A, 17, 23-A, 30, 35-A
Mouth washes	.132	37, 38-B, 38-C, 38-D, 38-F
Organo-silicone products	.576	2-B, 3-A
Pectin (processing)	.331	1, 2-B, 3-A, 13-A, 23-A, 30, 35-A
Perfume materials (processing)	.352	1, 2-B, 3-A, 12-A, 13-A, 30
Perfumes and perfume tinctures	.121	38-B, 39, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Petroleum products	.320	1, 2-B, 3-A
Photoengraving dyes and solutions	.481	1, 3-A, 13-A, 30, 32
Photographic chemicals (processing)	.353	1, 2-B, 3-A, 13-A, 30
Photographic film and emulsions	.031	1, 2-B, 3-A, 13-A, 19, 30, 32
Pill and tablet manufacture	.349	1, 2-B, 3-A, 13-A, 23-A, 30, 35-A, 38-B
Plastics, cellulose	.021	1, 2-B, 3-A, 12-A, 13-A, 30
Plastics, non-cellulose (including resins)	.022	1, 2-B, 3-A, 12-A, 13-A, 30
Polishes	.051	1, 3-A, 30, 40, 40-A, 40-B, 40-C
Preserving solutions	.430	1, 3-A, 12-A, 13-A, 22, 23-A, 30, 32, 37, 38-B, 42, 44
Proprietary solvents (standard formulas)	.041	1
Refrigerating uses	.740	1, 3-A, 23-A, 30
Resin coatings, natural	.014	1, 23-A
Resin coatings, synthetic	.012	1, 23-A, 30
Resins, synthetic	.590	3-A, 29, 30, 35-A
Room deodorants	.470	3-A, 22, 37, 38-B, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Rosin (processing)	.354	1, 3-A, 12-A
Rotogravure dyes and solutions	.481	1, 3-A, 13-A, 30, 32
Rubber (latex) (processing)	.355	1, 3-A
Rubber, synthetic	.580	29, 32
Rubbing alcohol	.220	23-H
Scientific instruments	.710	1, 3-A
Shampoos	.141	1, 3-A, 3-B, 23-A, 27-B, 31-A, 36, 38-B, 39-A, 39-B, 40, 40-A, 40-B, 40-C
Shellac coatings	.013	1, 23-A
Soaps, industrial	.440	1, 3-A, 23-A, 30
Soaps, toilet	.142	1, 3-A, 3-B, 23-A, 30, 36, 38-B, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Sodium ethylate, anhydrous (restricted)	.524	2-B
Sodium hydrosulfite (dehydraticn)	.312	1, 2-B, 3-A
Soldering flux	.035	1, 3-A, 23-A, 30
Solutions, miscellaneous	.485	1, 3-A, 23-A, 30, 39-B, 40, 40-A, 40-B, 40-C
Solvents and thinners, miscellaneous	.042	1, 23-A
Solvents, special (restricted sale)	.043	1, 3-A
Stains (wood)	.053	1, 3-A, 23-A, 30
Sterilizing solutions	.430	1, 3-A, 12-A, 13-A, 22, 23-A, 30, 32, 37, 38-B, 42, 44
Theater sprays	.470	3-A, 22, 37, 38-B, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Tobacco sprays and flavors	.460	4
Toilet waters	.122	38-B, 39, 39-A, 39-B, 39-C, 40, 40-A, 40-B, 40-C
Transparent sheetings	.032	1, 2-B, 3-A, 13-A, 23-A
Unclassified uses	.900	1, 3-A
Vaccine (processing)	.343	1, 2-B, 3-A, 12-A, 13-A, 23-A, 30, 32, 35-A
Vinegar	.511	18, 29, 35-A
Vitamins (processing)	.342	1, 2-B, 3-A, 12-A, 13-A, 23-A, 30, 32, 35-A
Xanthates	.573	1, 2-B, 2-C, 29
Yeast (processing)	.342	1, 2-B, 3-A, 12-A, 13-A, 23-A, 30, 32, 35-A

*Other products or processes may be authorized by the Director of the Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury, Washington, D.C.
Uses of Specially Denatured Alcohol—27 CFR 212.105

Table 6.41: Filmex Special Industrial Solvent Formulations *(30)*

Quantum's Filmex Solvents are typically used in flexographic printing for cleaning equipment, formulating and thinning inks and in producing rotogravure etchings; in the textile industry to promote adhesion, improve dye penetration and to soften fibers; in chemical and pharmaceutical processing; and in chemical specialties production, such as latex coagulants and lacquers, among others.

Code #	Proof	Formulation
		To every 100 gallons of ethyl alcohol, add:
Filmex A-1	190	5.0 gal. methyl alcohol 1.05 gal. methyl isobutyl ketone 10.5 lbs isopropyl alcohol, 99%
Filmex A-2	190	15.5 gal. methyl alcohol 1.05 gal. methyl isobutyl ketone
Filmex B	190	10.25 gal. methyl alcohol 1.05 gal. methyl isobutyl ketone 5.25 lbs isobutyl alcohol, 99%
Filmex C	190	5.0 gal. methyl alcohol 4.46 gal. ethyl acetate, 99% 1.05 gal. methyl isobutyl ketone
Filmex D-1	190	5.0 gal. methyl alcohol 1.05 gal. methyl isobutyl ketone 15.75 lb isopropyl alcohol, 99%
Filmex D-2	190	20.75 gal. methyl alcohol 1.05 gal. methyl isobutyl ketone

Filmex Solvents are also available in 200° (anhydrous) formulations.

Table 6.42: Completely Denatured Alcohol (CDA) Formulations *(30)*

CDA	Proof	Formulation	Applications
		To every 100 gallons of ethyl alcohol, add:	
CDA 19-1	190	4.0 gal. methyl isobutyl ketone 1.0 gal. kerosene, odorless	Cleaning fluids, antifreeze, thinners, detergents, brake fluids
CDA 19-3	190	4.0 gal. methyl isobutyl ketone 1.0 gal. rubber hydrocarbon solvent	Cleaning fluids, antifreeze, thinner, detergents, brake fluids
CDA 19-3	200	4.0 gal. methyl isobutyl ketone 1.0 gal. rubber hydrocarbon solvent	Cleaning fluids, detergents, antifreeze, thinners, brake fluids

Table 6.43: Proprietary Solvent Formulations *(30)*

Code #	Formulation	Applications
Propsolv I-1	100 gal. SDA 1-1 (190° or 200°) 1.0 gal. rubber hydrocarbon solvent 4.25 gal. ethyl acetate	Shellac, chemical specialties, latex coagulants
Propsolv I-2	100 gal. SDA 1-2 (190° or 200°) 1.0 gal. rubber hydrocarbon solvent 4.25 gal. ethyl acetate	Shellac, chemical specialties, latex coagulants
Propsolv III-1	100 gal. SDA 1-1 (190° or 200°) 1.0 gal. methyl isobutyl ketone 1.0 gal. rubber hydrocarbon solvent 0.87 gal. ethyl acetate	Shellac, chemical specialties, latex coagulants
Propsolv III-2	100 gal. SDA 1-2 (190° or 200°) 1.0 gal. methyl isobutyl ketone 0.87 gal. ethyl acetate 1.0 gal. rubber hydrocarbon solvent	Shellac, chemical specialties, latex coagulants

Table 6.44: Punctilious Specially Denatured Alcohol (SDA) Formulations *(30)*

SDA	Formulation	Applications
	To 100 gallons of 190° ethyl alcohol or, for anhydrous products, 200°, add:	
SDA 1-1	0.125 oz. Bitrex 4.0 gal. methanol	Coatings, solvents
SDA 1-2	4.0 gal. methanol 1.0 gal. methyl isobutyl ketone	Miscellaneous chemical manufacture
SDA 2B-2	0.50 gal. rubber hydrocarbon solvent	Pharmaceuticals, agricultural chemicals
SDA 2B-3	0.50 gal. toluene	Cosmetics and toiletries
SDA 2B-4	0.50 gal. Shell Solvent B	Plastics
SDA 3A	5.0 gal. methanol	Chemical specialties
SDA 3C	5.0 lb. isopropyl alcohol	Chemical intermediates
SDA 4	0.0022 lb. methylene blue 0.05 lb. nicotine, 40% soln 0.95 gal. water	Tobacco sprays
SDA 12A-3	5.0 gal. toluene	Chemical specialties
SDA 13A	10 gal. ethyl ether, USP	Miscellaneous chemical manufacture
SDA 19	100 gal. ethyl ether, USP	Miscellaneous chemical manufacture
SDA 23A	8.0 gal. acetone	External pharmaceuticals
SDA 23H	8.0 gal. acetone 1.5 gal. methyl isobutyl ketone	Pharmaceuticals and disinfectants
SDA 25-1	20.0 lb. iodine 15.0 lb. potassium iodide	Pharmaceuticals
SDA 25-2	20.0 lb. iodine 15.0 lb. sodium iodide	Pharmaceuticals
SDA 25A-1	20.0 lb. iodine 15.0 lb. potassium iodide 15.0 lb. water	Pharmaceuticals
SDA 25A-2	20.0 lb. iodine 15.0 lb. sodium iodide 15.0 lb. water	Pharmaceuticals
SDA 29-3	1.0 gal. ethyl acetate, 99% (ATF may approve other denaturants provided that amounts are not less than 6.8 lbs. of solid or 1.0 gal. of liquid/100 gal. ethyl alcohol)	Vinegar and other products
SDA 30	10.0 gal. methanol	Miscellaneous chemicals, solvents and drugs
SDA 32	5.0 gal. ethyl ether	Solvents, extractants, chemical specialties
SDA 35A-1	4.25 gal. ethyl acetate, 99%	Animal feed supplement, pill and tablet manufacturing
SDA 37	1.25 lb. menthol, natural 45.0 fl. oz. eucalyptol 30.0 av.oz. thymol	Pharmaceuticals, mouthwashes, antiseptic solutions
SDA 38B	10.0 lb. of any denaturant approved by the ATF for SDA 38B or any combination of approved denaturants adding up to 10.0 lbs.	Fragrances, toiletries, disinfectants, pharmaceuticals
SDA 38F	10.0 lb. of any denaturant approved by the ATF for SDA 38F or any combination of approved denaturants adding up to 10.0 lbs.	Pharmaceuticals, mouthwashes
SDA 39B	2.5 gal. diethyl phthalate, odorless 0.125 gal. t-butyl alcohol	Detergents, coatings, fungicides, pharmaceuticals
SDA 39	1.0 gal. diethyl phthalate, odorless or 1.0 gal. diethyl phthalate, regular	Fragrances
SDA 40-1	1.5 oz. brucine alkaloid 0.125 gal. t-butyl alcohol	Flavors and fragrances, hair sprays, disinfectants, insecticides, dye solutions
SDA 40-2	1.5 oz. brucine sulfate 0.125 gal. t-butyl alcohol	Flavors and fragrances, hair sprays, disinfectants, insecticides, dye solutions
SDA 40A	1.0 lb. sucrose octa-acetate 0.125 gal. t-butyl alcohol	Fragrances
SDA 40B	0.0625 oz. Bitrex 0.125 gal. t-butyl alcohol	Fragrances, cleaning solutions, household detergents, fungicides, polishes
SDA 40C	3.0 gal. t-butyl alcohol	Fragrances
SDA 45	300.0 lb. shellac	Candy glazes
Reagent Alcohol	5.0 gal. methyl alcohol 5.53 lb. isopropyl alcohol, 99%	Chemical reagents
Rubbing Alcohol Base	0.27 oz. Bitrex 8.0 gal. acetone 1.5 gal. methyl isobutyl ketone	Rubbing alcohol
Rubbing Alcohol Concentrate	0.27 oz. Bitrex 0.003 lb. menthol racemic 8.0 gal. acetone 1.5 gal. methyl isobutyl ketone	Rubbing alcohol

*Not all SDAs, formulations or applications can be presented here. For further information, contact your Quantum chemicals sales representative

Table 6.45: Composition and Typical End Uses of Specially Denatured Alcohols *(30)*

Specially Denatured Alcohol (SDA)	Ethanol[1]	Acetone N.F.	Methanol	Methyl Isobutyl Ketone	Isopropanol	t-Butanol	Ethyl Acetate	Toluene[4]
SDA 1	100 gal		4 gal	1 gal				
SDA 2B	100 gal							0.5 gal
SDA 3A	100 gal		5 gal					
SDA 3C	100 gal				5 gal			
SDA 23A	100 gal	8 gal						
SDA 23H	100 gal	8 gal		1.5 gal				
SDA 29[2]	100 gal						1 gal	
SDA 30	100 gal		10 gal					
SDA 35A	100 gal						4.25 gal	
SDA 37[3]	100 gal							
SDA 38B[3]	100 gal							
SDA 38F[3]	100 gal							
SDA 39C	100 gal							
SDA 40-2	100 gal					0.125 gal		
SDA 40B	100 gal					0.125 gal		

Specially Denatured Alcohol (SDA)	Diethyl Phthalate	Oils and Substances	Brucine Sulfate	Bitrex	Applications[6]
SDA 1					Solvent for coatings, adhesives, thinner, polishes.
SDA 2B					Solvent for processing food products, antibiotics and vaccines and dyes.
SDA 3A					Solvent for soap and bath preparations, latex processing, proprietary solvents.
SDA 3C					Solvent for shampoos, stains, processing food products, and cleaning solutions.
SDA 23A					Solvent for lotions and creams, soaps, antiseptic solutions, processing foods.
SDA 23H					Solvent for external pharmaceuticals, disinfectants, cleaning solutions.
SDA 29[2]					Vinegar manufacture, ethyl ether and ethylamines production.
SDA 30					Solvent for industrial detergents and soaps, dye solutions.
SDA 35A					Solvent for candy glazes, processing antibiotics, animal feed supplements.
SDA 37[3]		(5)			Mouthwashes, antiseptic solutions, USP or NF, room deodorants.
SDA 38B[3]		10 lb			Mouthwashes, deodorants, perfumes, soap and bath preparations.
SDA 38F[3]		10 lb			Mouthwashes, antiseptic solutions.
SDA 39C	1 gal				Lotions and creams, perfumes, soap and bath preparations.
SDA 40-2			1.5 av. oz		Hair preparations, lotions and creams, shampoos.
SDA 40B				0.063 av. oz	Hair preparations, lotions, and creams, shampoos.

(1) 190 and 200 proof formulations available
(2) Or permissible materials approved by BATF
(3) Denaturants may need to be supplied by customer
(4) Or rubber hydrocarbon solvent
(5) 45 fl oz eucalyptol, NF; 30 av oz thymol, NF; and 20 av oz menthol, USP
(6) For a more complete listing, see Codes of Federal Regulations, Vol 27, Part 21

Table 6.46: Composition of Completely Denatured Alcohol (CDA) *(19)*

Completely Denatured Alcohol (CDA)	Ethanol[1]	Methyl Isobutyl Ketone	Rubber Hydrocarbon Solvent
CDA 19	100 gal	4 gal	1 gal

Table 6.47: Composition of Synasol Proprietary Solvents, Anhydrol Special Industrial Solvents, and Inksolv Ink Solvents *(19)*

SYNASOL® Solvents	Ethanol	Methanol	Isopropanol	Methyl Isobutyl Ketone	Ethyl Acetate	n-Propyl Acetate	Approved Hydrocarbon
PM-41	SDA 1, 190 Proof, 100 gal				5 gal		1 gal
PM-100	SDA 1, 200 Proof, 100 gal				5 gal		1 gal
PM-3224	SDA 1, 190 Proof, 100 gal			1 gal	1 gal		1 gal
PM-509	SDA 1, 200 Proof, 100 gal			1 gal	1 gal		1 gal
ANHYDROL® Solvents							
PM-4079	SDA 3A, 190 Proof, 100 gal	10 gal		1 gal			
PM-4083	SDA 3A, 200 Proof, 100 gal	10 gal		1 gal			
PM-4078	SDA 3A, 190 Proof, 100 gal	15 gal		1 gal			
PM-4217	SDA 3A, 200 Proof, 100 gal	15 gal		1 gal			
PM-4081	SDA 3A, 190 Proof, 100 gal		10 gal	1 gal			
PM-4082	SDA 3A, 200 Proof, 100 gal		10 gal	1 gal			
PM-4080	SDA 3A, 190 Proof, 100 gal		15 gal	1 gal			
PM-4176	SDA 3A, 200 Proof, 100 gal		15 gal	1 gal			
PM-4085	SDA 3A, 190 Proof, 100 gal			1 gal	5 gal		
PM-4084	SDA 3A, 200 Proof, 100 gal			1 gal	5 gal		
PM-4157	SDA 3A, 190 Proof, 100 gal	5 gal	5 gal	1 gal			
PM-4135	SDA 3A, 200 Proof, 100 gal	5 gal	5 gal	1 gal			
INKSOLV® Solvents[1]							
PM-6127	SDA 3A, 190 Proof, 85 gal	14 gal				1 gal	
PM-6129	SDA 3A, 200 Proof, 85 gal	14 gal				1 gal	
PM-6118	SDA 3A, 200 Proof, 89 gal	10 gal				1 gal	
PM-6193	SDA 3C, 200 Proof, 89 gal		10 gal			1 gal	
PM-6264	SDA 3C, 200 Proof, 95 gal					5 gal	

(1) Additional non-methanol-containing formulas may be available on request

Table 6.48: Typical Physical Properties *(19)*

Product	Relative Evaporation Rate (BuAc=100)	Average Wt/gal at 60°F, lb	Δ lb/gal /Δ°F at 50-86°F	Coefficient of Expansion, per °C at 20°C	Coefficient of Expansion, per °C at 55°C	Flash Point, Closed Cup, °F	Flash Point, Closed Cup, °C	ASTM Distillation at 760 mm Hg, °C
INKSOLV® Solvents								
PM-6118	380	6.62	0.00399	0.00109	0.00113	57	14	—
PM-6127	390	6.77	0.00401	0.00107	0.00111	62	17	—
PM-6129	400	6.62	0.00403	0.00110	0.00114	59	15	—
PM-6193	280	6.62	0.00393	0.00107	0.00112	58	14	—
PM-6264	330	6.65	0.00401	0.00109	0.00113	55	13	—
ANHYDROL® Solvents								
PM-1473	210	6.77	0.00402	0.00107	0.00112	61	16	75.5-80.5
PM-1474	210	6.62	0.00402	0.00110	0.00114	55	13	75.5-80.5
PM-4081	320	6.76	0.00402	0.00108	0.00112	61	16	77.0-80.5
PM-4082	200	6.60	0.00398	0.00109	0.00113	57	14	77.0-80.5
PM-4079	360	6.77	0.00402	0.00107	0.00111	60	16	75.0-80.0
PM-4083	380	6.62	0.00402	0.00110	0.00114	58	14	74.0-80.0
PM-4157	330	6.74	0.00402	0.00108	0.00112	60	16	76.0-81.0
PM-4135	350	6.61	0.00402	0.00110	0.00114	56	13	76.0-80.0
PM-4085	370	6.81	0.00412	0.00109	0.00113	55	13	76.0-80.0
PM-4084	360	6.66	0.00412	0.00112	0.00116	53	12	75.0-79.0
PM-4080	330	6.75	0.00402	0.00107	0.00112	62	17	76.5-80.5
PM-4176	350	6.63	0.00398	0.00108	0.00113	58	14	77.0-82.0
PM-4078	370	6.76	0.00407	0.00109	0.00113	58	14	74.0-79.0
PM-4217	380	6.62	0.00407	0.00111	0.00116	55	13	74.0-79.0
SYNASOL® Solvents								
PM-0041	350	6.80	0.00413	0.00110	0.00114	53	12	74.5-79.5
PM-0100	410	6.66	0.00410	0.00111	0.00116	47	8	74.5-79.5
PM-3224	360	6.78	0.00406	0.00108	0.00118	57	14	74.5-79.5
PM-0509	360	6.62	0.00406	0.00111	0.00120	51	11	74.5-79.5
Completely Denatured Alcohol (CDA)								
Ethanol CD-19								
190 Proof	290	6.79	0.00407	0.00109	0.00113	54	12	76.0-82.0
200 Proof	330	6.61	0.00402	0.00110	0.00114	51	11	76.0-82.0
Specially Denatured Alcohol (SDA)								
Ethanol SDA-2B								
190 Proof	300	6.80	0.00394	0.00105	0.00109	58	14	77.0-80.0
200 proof	330	6.61	0.00395	0.00107	0.00113	55	13	77.0-80.0
Ethanol SDA-3A								
190 Proof	320	6.78	0.00403	0.00107	0.00112	62	17	76.0-80.0
200 Proof	360	6.62	0.00398	0.00110	0.00111	56	13	76.0-80.0
Ethanol SD-4								
190 Proof	290	6.82	0.00403	0.00107	0.00111	63	17	—
Ethanol SD-23A								
190 Proof	370	6.78	0.00412	0.00111	0.00115	44	7	—
200 Proof	410	6.63	0.00416	0.00113	0.00121	37	3	—
Ethanol SD-23H								
190 Proof	390	6.78	0.00416	0.00111	0.00115	55	13	—
Ethanol SD-29H								
190 Proof	290	6.80	0.00401	0.00107	0.00111	63	17	—
200 Proof	340	6.62	0.00396	0.00108	0.00112	57	14	—
Ethanol SD-29E								
190 Proof	290	6.79	0.00402	0.00107	0.00111	60	16	76.0-79.0
Ethanol SD-30								
190 Proof	330	6.78	0.00403	0.00107	0.00112	60	16	76.0-80.0
200 Proof	370	6.62	0.00398	0.00109	0.00113	59	15	76.0-80.0
Ethanol SD-35A								
190 Proof	310	6.83	0.00410	0.00109	0.00113	57	14	76.0-79.0
200 Proof	340	6.66	0.00407	0.00111	0.00115	52	11	76.0-79.0

(continued)

Table 6.48: (continued)

Product	Relative Evaporation Rate (BuAc=100)	Average Wt/gal at 60°F, lb	Δ lb/gal /Δ°F at 50-86°F	Coefficient of Expansion, per °C at 20°C	at 55°C	Flash Point, Closed Cup, °F	°C	ASTM Distillation at 760 mm Hg, °C
Ethanol SD-37								
190 Proof	280	6.79	0.00402	0.00107	0.00111	61	16	—
Ethanol SD-38B								
190 Proof	300	6.80	0.00399	0.00106	0.00110	63	17	—
Ethanol SD-38F								
190 Proof	280	6.83	0.00402	0.00107	0.00111	63	17	—
Ethanol SD-39C								
190 Proof	300	6.81	0.00403	0.00107	0.00111	61	16	76.0-80.0
200 Proof	330	6.62	0.00398	0.00107	0.00111	57	14	76.0-80.0
Ethanol SD-40								
190 Proof	290	6.79	0.00401	0.00107	0.00111	61	16	77.0-80.0
200 Proof	330	6.62	0.00402	0.00110	0.00114	58	14	77.0-80.0
Ethanol SD-40A								
190 Proof	290	6.79	0.00402	0.00107	0.00111	62	17	—
200 Proof	310	6.62	0.00397	0.00109	0.00113	58	14	—
Ethanol SD-40B								
190 Proof	300	6.79	0.00400	0.00107	0.00111	62	17	77.0-80.0
200 Proof	330	6.61	0.00396	0.00108	0.00116	57	14	77.0-80.0
Ethanol SD-40C								
200 Proof	330	6.61	0.00395	0.00108	0.00112	59	15	77.0-80.0
Pure Alcohols								
190 Proof	300	6.79	0.00403	0.00107	0.00111	62	17	78.2
200 Proof	330	6.61	0.00398	0.00109	0.00113	58	14	78.3

Table 6.49: Densities of Pure Ethanol-Water Mixtures at Various Temperatures *(19)*

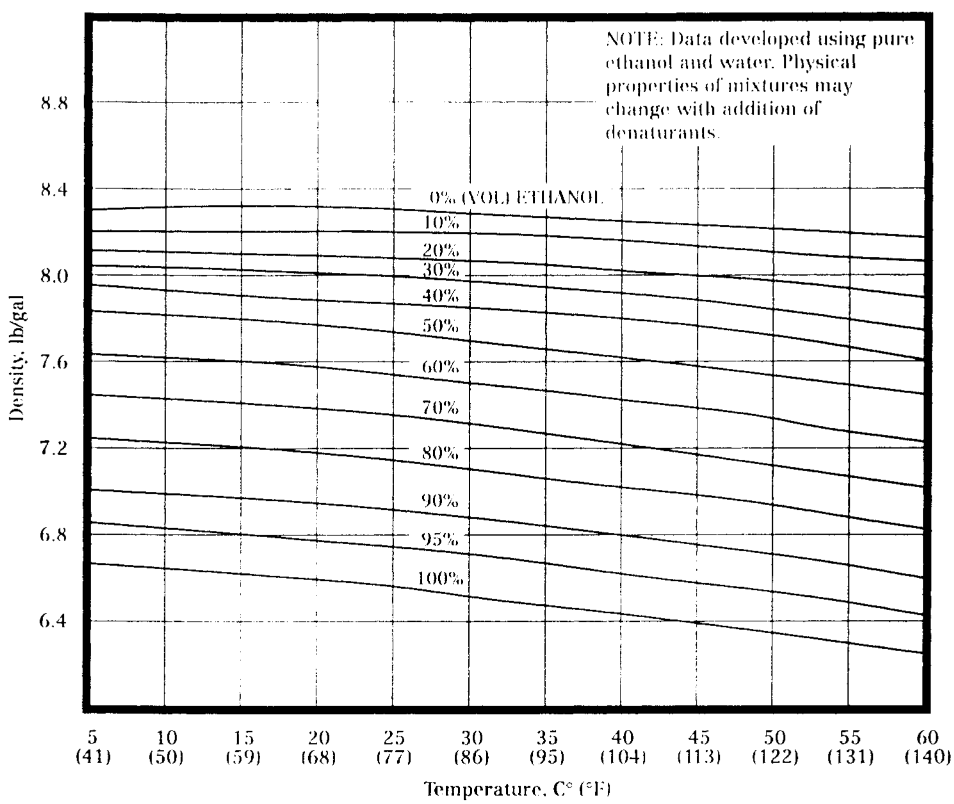


Table 6.50: Vapor Pressure of Pure Ethanol at Various Temperatures *(19)*

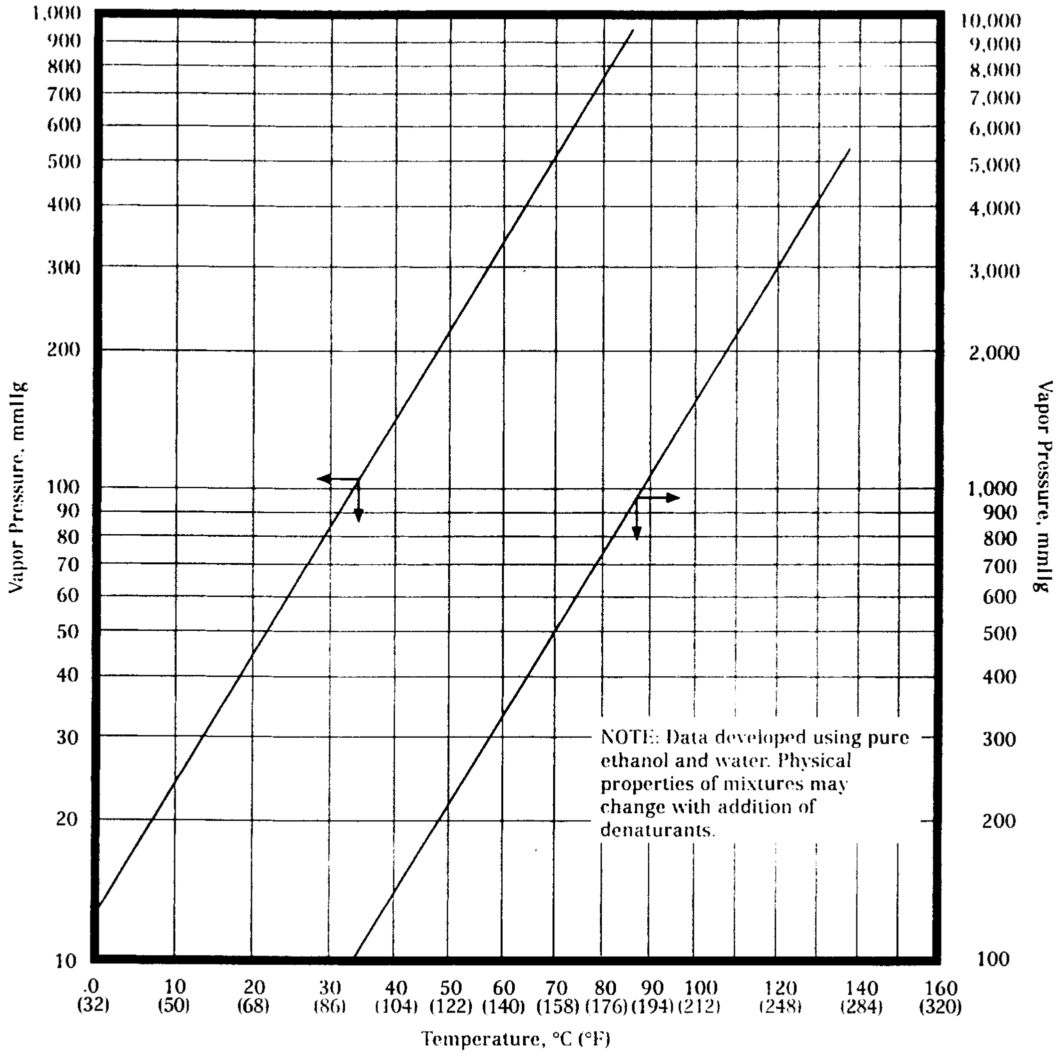


Table 6.51: Constant Boiling Mixtures *(19)*

COMPONENTS			AZEOTROPE		
Compound[1]	Specific Gravity at 20/20°C	Boiling point at 760 mm Hg, °C	Boiling Point at 760 mm Hg, °C	Composition in Azeotrope, % by wt	Sp Gr of Azeotrope or Layers at 20/20°C
Ethanol	0.7905	78.3	42.4	9.0	
Carbon Disulfide	1.2657	46.5		91.0	1.197
Ethanol	0.7905	78.3	41.3	5.0	Homogeneous
Carbon Disulfide	1.2657	46.5		93.4	
Water	1.0000	100.0		1.6	
Ethanol	0.7905	78.3	65.0	15.8	1.377
Carbon Tetrachloride	1.5875	76.5		84.2	
Ethanol	0.7905	78.3	61.8	10.3	U 0.935
Carbon Tetrachloride	1.5875	76.5		86.3	L 1.519
Water	1.0000	100.0		3.4	
Ethanol	0.7905	78.3	59.4	7.0	1.403
Chloroform	1.4756	61.2		93.0	
Ethanol	0.7905	78.3	55.5	4.0	U 0.976
Chloroform	1.4756	61.2		92.5	L 1.519
Water	1.0000	100.0		3.5	

(continued)

Table 6.51: (continued)

COMPONENTS			AZEOTROPE		
Compound[1]	Specific Gravity at 20/20°C	Boiling point at 760 mm Hg, °C	Boiling Point at 760 mm Hg, °C	Composition in Azeotrope, % by wt	Sp Gr of Azeotrope or Layers at 20/20°C
Ethanol	0.7905	78.3	62.6	19.7	Homogeneous
Cyclohexane	0.7797	80.7		75.5	
Water	1.0000	100.0		4.8	
Ethanol	0.7905	78.3	71.8	31.0	0.863
Ethyl Acetate	0.9018	77.2		69.0	
Ethanol	0.7905	78.3	70.2	8.4	0.901[2]
Ethyl Acetate	0.9018	77.2		82.6	
Water	1.0000	100.0		9.0	
Ethanol	0.7905	78.3	71.0	33.5	1.049
Ethylene Dichloride	1.2556	83.5		66.5	
Ethanol	0.7905	78.3	67.8	15.7	U 0.941
Ethylene Dichloride	1.2556	83.5		77.1	L 1.167
Water	1.0000	100.0		7.2	
Ethanol	0.7905	78.3	72	48.0	0.729
Heptane	0.6845	98.4		52.0	
Ethanol	0.7905	78.3	68.8	33.0	U 0.686
Heptane	0.6845	98.4		60.9	L 0.801
Water	1.0000	100.0		6.1	
Ethanol	0.7905	78.3	58.7	21.0	0.687
Hexane	0.6601	68.7		79.0	
Ethanol	0.7905	78.3	56	12.0	U 0.672
Heptane	0.6601	68.7		85.0	L 0.833
Water	1.0000	100.0		3.0	
Ethanol	0.7905	78.3	74.8	19.4	0.874
Isopropyl Acetate	0.8737	88.5		70.8	
Water	1.0000	100.0		9.8	
Ethanol	0.7905	78.3	64.0	17.1	0.741
Isopropyl Ether	0.7245	68.5		82.9	
Ethanol	0.7905	78.3	61.0	6.5	U 0.737
Isopropyl Ether	0.7245	68.5		89.5	L 0.967
Water	1.0000	100.0		4.0	
Ethanol	0.7905	78.3	74.8	34.0	0.802
Methyl Ethyl Ketone	0.8061	79.6		66.0	
Ethanol	0.7905	78.3	73.2	14.0	0.832
Methyl Ethyl Ketone	0.8061	79.6		75.0	
Water	1.0000	100.0		11.0	
Ethanol	0.7905	78.3	34.3	5.0	
Pentane	0.6269	36.1		95.0	
Ethanol	0.7905	78.3	76.7	68.0	0.815
Toluene	0.8683	110.6		32.0	
Ethanol	0.7905	78.3	74.4	37.0	U 0.849
Toluene	0.8683	110.6		51.0	L 0.855
Water	1.0000	100.0		12.0	
Ethanol	0.7905	78.3	70.9	27.0	1.197
Trichloroethylene	1.4655	87.1		73.0	
Ethanol	0.7905	78.3	76.9	51.0	0.775
Triethylamine	0.7290	89.5		49.0	
Ethanol	0.7905	78.3	74.7	15.0	0.774
Triethylamine	0.7290	89.5		75.0	
Water	1.0000	100.0		10.0	
Ethanol (95 mm)	0.7905	33.5[3]	33.4[3]	99.5	0.792
Water	1.0000	51.0[3]		0.5	
Ethanol	0.7905	78.3	78.2	95.6	0.804
Water	1.0000	100.0		4.4	
Ethanol (3 atm)	0.7905	109.0[3]	109.0[3]	95.2	0.805
Water	1.0000	134.0[3]		4.8	

(1) The ethanol listed as a compound in this table is pure. Azeotropes vary with the addition of denaturants.
(2) At 25/20°C
(3) At the pressure investigated
NONAZEOTROPES: In binary systems with ethanol and ternary systems with ethanol and water, these materials do not form azeotropes: Acetone, Butanol, 1,4-Dioxane, Ethyl Ether, Methanol, m-Xylene, o-Xylene, p-Xylene, Water-Methanol

Table 6.52: Proof Definitions and Conversion Factors *(19)*

Proof: The ethanol content of a liquid at 60°F (15.56°C) stated as twice the percent of ethanol by volume.
Proof = 2 x volume percent ethanol in a liquid (at 60°F)

Apparent Proof: The equivalent of proof for ethanol solutions containing ingredients other than water (i.e., denatured alcohol). Apparent proof is determined by specific gravity readings for ethanol-water mixtures at 60/60°F.

Proof Gallon: Amount of ethanol in one wine gallon of 100 proof alcohol at 60°F.
Proof gallons = wine gallons at 60°F x 100/proof

Wine Gallon: A United States gallon of liquid measure equivalent to the volume of 231.2 cubic inches.
1 Wine gallon = 231.2 cubic inches

Tax Gallon: The unit measure of spirits for the imposition of tax under section 5001, IRC. For spirits that are 100 degrees of proof or more when withdrawn from bond, the tax is determined on a proof gallon basis. When less than 100 degrees of proof, the tax is determined on a wine gallon basis. Table 6.53 covers ethanol-water compositions from 0 to 200 proof. Keep in mind that, because of the contraction that occurs when ethanol and water are mixed, 100 volumes of ethanol of the designated proof result from mixing the volumes of ethanol and water given in columns 2 and 4.

Table 6.53: Proof Conversion Tables *(19)*

	Pure 200 Proof			
Proof at 60°F	Ethanol, Parts by Volume at 60°F	Ethanol, % by Weight at 60°F	Water, Parts by Volume at 60°F	Specific Gravity at 60/60°F
0	0.0	0.00	100.00	1.0000
1	0.5	0.39	99.53	0.9993
2	1.0	0.80	99.06	0.9985
3	1.5	1.19	98.58	0.9978
4	2.0	1.59	98.12	0.9970
5	2.5	1.99	97.65	0.9963
6	3.0	2.39	97.18	0.9956
7	3.5	3.79	96.71	0.9949
8	4.0	3.19	96.24	0.9942
9	4.5	3.60	95.78	0.9935
10	5.0	4.00	95.31	0.9928
11	5.5	4.40	94.85	0.9921
12	6.0	4.80	94.39	0.9915
13	6.5	5.21	93.93	0.9908
14	7.0	5.61	93.46	0.9902
15	7.5	6.02	93.01	0.9896
16	8.0	6.42	92.55	0.9890
17	8.5	6.83	92.09	0.9884
18	9.0	7.23	91.63	0.9878
19	9.5	7.64	91.18	0.9872
20	10.0	8.05	90.72	0.9866
21	10.5	8.45	90.27	0.9860
22	11.0	8.86	89.81	0.9854
23	11.5	9.27	89.36	0.9849
24	12.0	9.68	88.90	0.9843
25	12.5	10.09	88.45	0.9837
26	13.0	10.50	88.00	0.9832
27	13.5	10.91	87.55	0.9826
28	14.0	11.32	87.10	0.9821
29	14.5	11.73	86.65	0.9816
30	15.0	12.14	86.20	0.9810
31	15.5	12.55	85.75	0.9805
32	16.0	32.96	85.30	0.9800
33	16.5	13.37	84.85	0.9794
34	17.0	13.79	84.40	0.9789
35	17.5	14.20	83.95	0.9784
36	18.0	14.61	83.50	0.9779
37	18.5	15.03	83.06	0.9774
38	19.0	15.44	82.61	0.9769
39	19.5	15.85	82.16	0.9764
40	20.0	16.27	81.72	0.9759
41	20.5	16.68	81.27	0.9754
42	21.0	17.10	80.82	0.9749
43	21.5	17.52	80.38	0.9744
44	22.0	17.93	79.93	0.9739
45	22.5	18.35	79.48	0.9734
46	23.0	18.77	79.03	0.9729
47	23.5	19.19	78.58	0.9724
48	24.0	19.60	77.14	0.9719
49	24.5	20.02	77.69	0.9713
50	25.0	20.44	77.24	0.9708
51	25.5	20.86	76.79	0.9703
52	26.0	21.29	76.34	0.9697
53	26.5	21.71	75.89	0.9692
54	27.0	22.13	75.44	0.9687
55	27.5	22.50	74.98	0.9681
56	28.0	22.97	74.53	0.9676
57	28.5	23.40	74.08	0.9670
58	29.0	23.82	73.62	0.9664
59	29.5	24.24	73.17	0.9659
60	30.0	24.67	72.72	0.9653
61	30.5	25.10	72.26	0.9647
62	31.0	25.52	71.81	0.9641
63	31.5	25.95	71.35	0.9635
64	32.0	26.38	70.89	0.9629
65	32.5	26.81	70.43	0.9623
66	33.0	27.24	69.97	0.9617
67	33.5	27.67	69.51	0.9619
68	34.0	28.10	69.05	0.9604
69	34.5	28.53	68.59	0.9597
70	35.0	28.97	68.12	0.9590
71	35.5	29.41	67.66	0.9584
72	36.0	29.84	67.19	0.9577
73	36.5	30.28	66.72	0.9570
74	37.0	30.72	66.25	0.9652
75	37.5	31.16	65.78	0.9555
76	38.0	31.60	65.31	0.9548
77	38.5	32.04	64.84	0.9540
78	39.0	32.48	64.37	0.9533
79	39.5	32.92	63.90	0.9525

(continued)

Table 6.53: (continued)

Proof at 60°F	Pure 200 Proof Ethanol, Parts by Volume at 60°F	Pure 200 Proof Ethanol, % by Weight at 60°F	Water, Parts by Volume at 60°F	Specific Gravity at 60/60°F
80	40.0	33.36	63.42	0.9517
81	40.5	33.81	62.95	0.9509
82	41.0	34.25	62.47	0.9501
83	41.5	34.70	61.99	0.9493
84	42.0	35.15	61.52	0.9485
85	42.5	35.60	610.04	0.9474
86	43.0	36.05	60.56	0.9469
87	43.5	36.50	60.08	0.9460
88	44.0	36.96	59.59	0.9452
89	44.5	37.41	59.11	0.9443
90	45.0	37.87	58.63	0.9434
91	45.5	38.32	58.14	0.9426
92	46.0	38.78	57.66	0.9417
93	46.5	39.24	57.17	0.9408
94	47.0	39.70	56.68	0.9399
95	47.5	40.16	56.19	0.9389
96	48.0	40.62	55.70	0.9380
97	48.5	41.09	55.21	0.9371
98	49.0	41.55	54.72	0.9361
99	49.5	42.02	54.22	0.9352
100	50.0	42.49	53.73	0.9342
101	50.5	42.96	53.24	0.9332
102	51.0	43.43	52.74	0.9322
103	51.5	43.90	52.25	0.9312
104	52.0	44.37	51.75	0.9302
105	52.5	44.85	51.25	0.9292
106	53.0	45.33	50.75	0.9282
107	53.5	45.80	50.26	0.9272
108	54.0	46.28	49.76	0.9262
109	54.5	46.76	49.26	0.9252
110	55.0	47.25	48.76	0.9241
111	55.5	47.73	48.25	0.9231
112	56.0	48.21	47.75	0.9220
113	56.5	48.70	47.25	0.9210
114	57.0	49.19	46.75	0.9199
115	57.5	49.68	46.24	0.9188
116	58.0	50.17	45.74	0.9177
117	58.5	50.66	45.23	0.9167
118	59.0	51.15	44.72	0.9156
119	59.5	51.65	44.22	0.9144
120	60.0	52.15	43.71	0.9133
121	60.5	52.65	43.20	0.9122
122	61.0	53.15	42.69	0.9111
123	61.5	53.65	42.18	0.9100
124	62.0	54.15	41.67	0.9088
125	62.5	54.66	41.16	0.9077
126	63.0	55.17	40.65	0.9065
127	63.5	55.67	40.14	0.9054
128	64.0	56.18	39.62	0.9042
129	64.5	56.70	39.11	0.9031
130	65.0	57.21	38.60	0.9019
131	65.5	57.72	38.08	0.9007
132	66.0	58.24	37.57	0.8996
133	66.5	58.76	37.05	0.8984
134	67.0	59.28	36.54	0.8972
135	67.5	59.80	36.02	0.8969
136	68.0	60.33	35.50	0.8948
137	68.5	60.85	34.99	0.8936
138	69.0	61.38	34.47	0.8923
139	69.5	61.91	33.95	0.8911
140	70.0	62.44	33.43	0.8899
141	70.5	62.98	32.91	0.8886
142	71.0	63.51	32.38	0.8874
143	71.5	64.05	31.86	0.8861
144	72.0	64.59	31.34	0.8849
145	72.5	65.13	30.82	0.8836
146	73.0	65.67	30.29	0.8823
147	73.5	66.22	29.76	0.8810
148	74.0	66.77	29.24	0.8797
149	74.5	67.32	28.71	0.8784
150	75.0	67.87	28.19	0.8771
151	75.5	68.43	27.66	0.8758
152	76.0	68.98	27.13	0.8745
153	76.5	69.54	26.60	0.8732
154	77.0	70.10	26.07	0.8718
155	77.5	70.67	25.54	0.8705
156	78.0	71.23	25.01	0.8691
157	78.5	71.80	24.47	0.8678
158	79.0	72.38	23.94	0.8664
159	79.5	72.95	23.40	0.8650
160	80.0	73.53	22.87	0.8636
161	80.5	74.11	22.33	0.8623
162	81.0	74.69	21.80	0.8608
163	81.5	75.27	21.26	0.8594
164	82.0	75.86	20.72	0.8580
165	82.5	76.45	20.18	0.8566
166	83.0	77.04	19.64	0.8552
167	83.5	77.64	19.10	0.8537
168	84.0	78.23	18.55	0.8522
169	84.5	78.84	18.01	0.8508
170	85.0	79.44	17.46	0.8493
171	85.5	80.05	16.92	0.8478
172	86.0	80.62	16.37	0.8463
173	86.5	81.28	15.82	0.8447
174	87.0	81.90	15.27	0.8432
175	87.5	82.52	14.72	0.8416
176	88.0	83.14	14.16	0.8401
177	88.5	83.78	13.61	0.8385
178	89.0	84.41	13.05	0.8369
179	89.5	85.05	12.49	0.8353
180	90.0	85.69	11.93	0.8336
181	90.5	86.34	11.37	0.8320
182	91.0	86.99	10.80	0.8303
183	91.5	87.65	10.24	0.8286
184	92.0	88.31	9.67	0.8269
185	92.5	88.98	9.09	0.8251
186	93.0	89.65	8.52	0.8233
187	93.5	90.34	7.94	0.8215
188	94.0	91.03	7.36	0.8196
189	94.5	91.72	6.77	0.8178
190	95.0	92.42	6.18	0.8158
191	95.5	93.14	5.59	0.8139
192	96.0	93.85	4.99	0.8118
193	96.5	94.58	4.39	0.8098
194	97.0	95.32	3.78	0.8077
195	97.5	96.07	3.17	0.8056
197	98.5	97.60	1.93	0.8010
198	99.0	98.38	1.29	0.7987
199	99.5	99.19	0.65	0.7962
200	100.0	100.0	0.00	0.7937

Table 6.54: Azeotropes of Ethanol *(31)*

ETHYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
79	tert-Amyl ethyl ether	66.6
67.6	Benzene	68.3
57	1-Bromobutane	75.0
67	2-Bromobutane	72.5
22.5	cis-1-Bromo-1-butene	69.6
64.3	trans-1-Bromo-1-butene	72.8
66.3	cis-2-Bromo-2-butene	72.3
73.3	trans-2-Bromo-2-butene	69.1
77.8	2-Bromo-1-butene	67.4
18	1-Bromo-3-methylbutane	77.3
59	1-Bromo-1-methylpropane	71.4
85	2-Bromo-2-methylpropane	63.8
83.7	1-Bromopropane	63.6
88.5	2-Bromopropane	55.5
94	2-Bromopropene	46.2
89	trans-1-Bromopropene	58.7
91	cis-1-Bromopropene	56.4
79	tert-Butyl ethyl ether	66.6
91	Carbon disulfide	42.4
84.2	Carbon tetrachloride	64.9
79.7	1-Chlorobutane	65.7
84.2	2-Chlorobutane	61.2
85.2	cis-1-Chloro-1-butene	57.0
79.8	trans-1-Chloro-1-butene	61.2
88.5	2-Chloro-1-butene	53.6
84.6	cis-2-Chloro-2-butene	56.8
93.0	Chloroform	59.4
59	1-Chloro-3-methylbutane	74.8
83.7	1-Chloro-2-methylpropane	61.5
94	1-Chloropropane	46.7
97.2	2-Chloropropane	36.6
96	trans-1-Chloropropene	36.7
95	3-Chloropropene	44.0
66	1,3-Cyclohexadiene	60.7
69.5	Cyclohexane	64.9
66	Cyclohexene	66.7
92.5	Cyclopentane	44.7
47.2	1,1-Dichloropropane	74.7
85.5	2,2-Dichloropropane	63.2
41	2,5-Dimethylhexane	73.6
58	Diethoxymethane	74.2
69	Ethyl acetate	71.8
27.3	Ethyl acrylate	77.5
25	Ethyl propionate	78.0
75	Ethyl propyl ether	61.2
44	Ethyl sulfide	72.6
75	Fluorobenzene	70.0
51	n-Heptane	70.9
79	n-Hexane	58.6
30	2-Iodobutane	77.2
30	1-Iodo-2-methylpropane	77.0
56	1-Iodopropane	75.4
75	2-Iodopropane	70.2
58	3-Iodopropene	75.4
33	Isobutyl formate	77.0
97	Isoprene	32.7
47	Isopropyl acetate	76.8
97	Methyl acetate	56.9
57.6	Methyl acrylate	73.5
75	Methyl borate	63.0
96.5	2-Methylbutane	26.8
17	Methyl butyrate	78.0
55	Methyl carbonate	73.5
72	Methylcyclopentene	63.3
75	Methylcyclopentene	60.3
66	Methyl ethyl ketone	74.8
67	Methyl propionate	72.0
22	Octane	77.0
95	Pentane	34.3
8.8	2-Pentanone	77.7
19	Perchloroethylene	78.0
81	Propanediol	63.5
15	Propyl acetate	78.2
56	Propyl ether	74.4
55	Thiophene	70.0
32	Toluene	76.7
73	Trichloroethylene	70.9

ETHYL ALCOHOL FORMS TERNARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
11.4	Water	77.8
61	Acetal	
74	Water	64.9
74.1	Benzene	
7.4	Water	72.0
70	Bromodichloromethane	
8	Water	69.5
65	1-Bromo-2-methylpropane	
3	Water	54.0
91	cis-1-Bromopropane	
4	Water	54.5
7.5	trans-Bromopropane	
5	Water	60.0
83	1-Bromopropane	
1	Water	43.3
95	2-Bromopropane	
1.6	Water	41.3
3.4	Carbon disulfide	
3.5	Water	55.4
92.5	Chloroform	
4.5	Water	58.6
82.5	1-Chloro-2-methylpropane	
7	Water	64.1
73	Cyclohexene	
5	Water	66.7
78	1,2-Dichloroethane	
2.85	Water	53.8
90.5	cis-1,2-Dichloroethylene	
1.1	Water	44.4
94.5	trans-1,2-Dichloroethylene	
12.8	Water	73.2
69.5	Dimethoxymethane	
9	Water	70.2
82.6	Ethyl acetate	
17.5	Water	81.4
20.8	Ethyl chloroacetate	
5.5	Water	67.0
78.4	Trichloroethylene	
9	Water	74.7
78	Triethylamine	

n-PROPYL ALCOHOL

n-Propanol $CH_3CH_2CH_2OH$

n-Propyl alcohol is a colorless, volatile liquid.

Table 6.55: Physical Properties of n-Propyl Alcohol *(31)*

Acidity as acetic acid	0.003% by wt, max.
Alkalinity as ammonia	0.003% by wt, max.
Autoignition temperature	540°C
Boiling point at 760 mm	97.15°C
Coefficient of cubical expansion, 0 - 94°C	0.000956×10^{-3}
Color, APHA	5 max.
Critical density	0.2734
Critical pressure	49.9 atm
Critical temperature	263.7°C
Distillation range at 760 mm	2°C including 97.15°C
Electrical conductivity, mhos per cm at 25°C	2×10^{-8}
Explosive limits, Lower	2.6% by vol. in air
Upper	13.5% by vol. in air
Fire hazard	Dangerous when exposed to heat or flame.
Flash point (open cup)	90°F
(closed cup)	59°F
Freezing point	-127°C (-196°F)
Heat of combustion	8020 cal/g
Heat of vaporization at 97.15°C	162.6 cal/g
Limits of flammability (in air by volume)	2.5% (Lower)
Melting point	-127.0°C
Molecular weight	60.09
Non-volatile material	0.001 gm/100 ml sample, max.
Odor	Alcohol-like
Refractive index at 20°C	1.3845
Reid vapor pressure at 100°F	0.1 psi
Relative evaporation rate (butyl acetate = 1)	1.3
Specific gravity at 20/4°C	0.8036
at 20/20°C	0.8050
Specific heat at 25°C	0.586 cal/g/°C
Surface tension in air, -5°C	25.9 dynes/cm
20°C	23.8 dynes/cm
60°C	20.5 dynes/cm
Toxicity	Slight

Vapor pressure °C	°F	mm Hg
0	32	3.44
10	50	7.26
20	68	14.5
30	86	27.6
40	104	50.2
50	122	87.2
60	140	147.0
70	158	239.0
80	176	376.0
90	194	574.0
97.19	206.9	760.0

Viscosity, 0°C	3.8827 centipoises
20°C	2.2563 centipoises
40°C	1.4050 centipoises
90°C	0.5310 centipoises
Water content	0.2% by wt, max.
Weight per gallon at 20°C (68°F)	6.7 lbs

Table 6.56: Azeotropes of n-Propyl Alcohol *(31)*

n-PROPYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
63	Acetal	92.4
83.1	Benzene	77.1
75	Biacetyl	85.0
31	1-Bromobutane	89.5
89.5	2-Bromobutane	85.3
82	n-Butyl chloride	74.8
36	Butyl formate	95.5
88.5	Carbon tetrachloride	73.1
17	Chlorobenzene	96.9
82	1-Chlorobutane	74.8
91	2-Chlorobutane	67.2
69	1-Chloro-3-methylbutane	89.4
78	1-Chloro-2-methylpropane	67.7
89	Diethoxymethane	86.2
45	Dioxane	95.3
70	Di-n-propyl ether	85.7
49	Ethyl propionate	93.4
72	Ethyl sulfide	85.5
81	Ethylene chloride	80.7
82	Fluorobenzene	80.2
96	n-Hexane	65.7
34	1-Iodobutane	96.2
47	2-Iodobutane	94.2
55	1-Iodo-2-methylpropane	93.0
60	Isobutyl formate	93.2
30	Isobutyronitrile	95.0
94.6	Methyl acrylate	70.9
65	3-Methyl-2-butanol	93.5
53	Methyl butyrate	94.4
74	Methyl isobutyrate	89.5
32	2-Pentanone	96.0
37	3-Pentanone	96.0
1.5	α-Pinene	97.1
60	Propyl acetate	94.2
91	n-Propyl bromide	69.7
90.2	Propyl formate	80.6
47.5	Toluene	92.4
28.3	Water	87.7

n-PROPYL ALCOHOL FORMS TERNARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
27.4	Water	
21	Acetaldehyde dipropylacetal	87.6
7.6	Water	
82.3	Benzene	67.0
5	Water	
84	Carbon tetrachloride	65.4
9	Water	
79	1,3-Cyclohexadiene	67.8
8.5	Water	
81.5	Cyclohexane	66.6
9	Water	
79.5	Cyclohexene	63.2
8	Water	
47.2	Dipropoxymethane	86.4
17.6	Water	
59.5	Ethoxypropoxymethane	83.8
8	Water	
72	3-Iodopropene	78.2
17.5	Water	
55.9	Nitromethane	82.3
20	Water	
60	3-Pentanone	81.2
21	Water	
59.5	Propyl acetate	82.2
25.3	Water	
16.5	Propyl chloroacetate	88.6
11.7	Water	
68.1	Propyl ether	74.8
13	Water	
82	Propyl formate	70.8
7	Water	
81	Trichloroethylene	71.6

Table 6.57: n-Propanol-Water-Benzene *(19)*

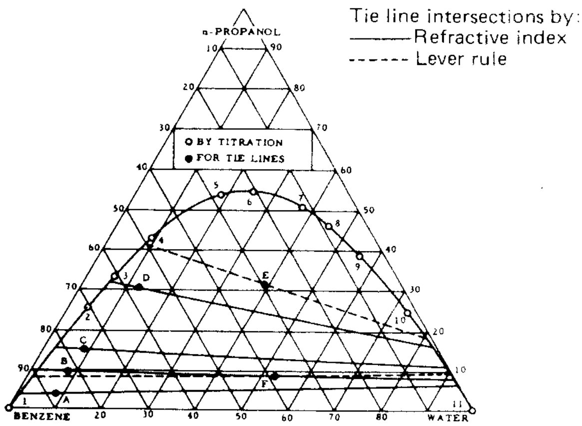


Table 6.58: n-Propanol-Water-n-Butanol *(19)*

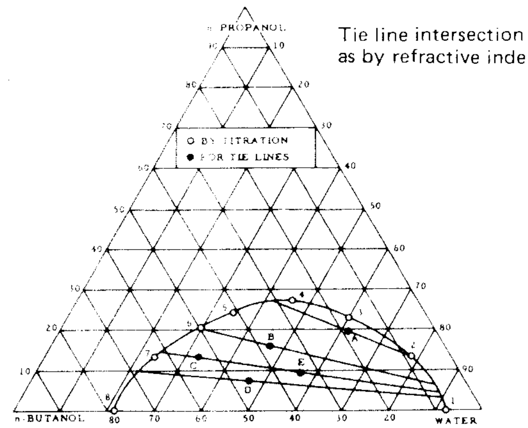


Table 6.59: n-Propanol-Water-Heptane *(19)*

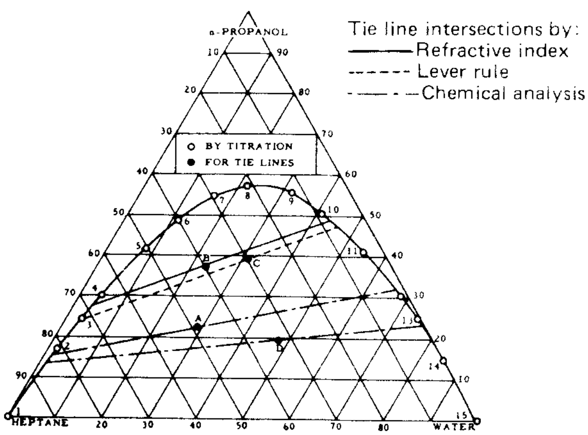
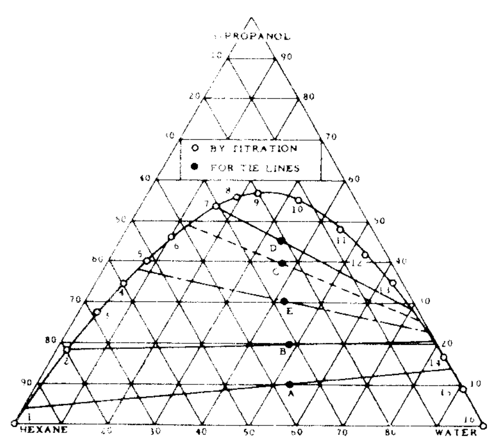


Table 6.60: n-Propanol-Water-Hexane *(19)*



ISOPROPYL ALCOHOL

Isopropanol, Dimethyl Carbinol, 2-Propanol $(CH_3)_2CHOH$

Table 6.61: Physical Properties of Anhydrous Isopropyl Alcohol *(31)*

Acidity, as acetic acid	0.002% by wt, max.
Boiling point at 760 mm	82.3°C
50 mm	27°C
10 mm	2°C
Coefficient of expansion at 55°C	0.00111
Color, Pt-Co scale	10 max.
Critical pressure	53 atm.
Critical temperature	234.9°C
Dielectric constant at 20°C	18.62
40°C	16.24
80°C	11.91
Distillation at 760 mm	Distills entirely within 1.0°C range which includes 82.3°C
Fire hazard	Dangerous when exposed to heat or open flame
Flash point (open cup)	70°F
Freezing point	-87.8°C
Heat of combustion	7970 cal/g 7942 cal/g
Heat of fusion	21.08 cal/g
Heat of vaporization	287 Btu/lb
Lower limit of flammability in air	2.65% vol.
MAC	400 ppm in air
Molecular weight	60.09
Non-volatile matter	0.002 g/100 ml, max.
Odor	Non-residual
Purity	99.5% - 99.9% by vol.
Refractive index at 20°C	1.3772
Specific gravity at 20/20°C	0.7862 - 0.7867
Specific heat at 20°C	0.596 cal/g/°C
Surface tension at 25°C	20.8 dynes/cm
Toxicity	Moderate by ingestion; otherwise slight
Vapor pressure at 20°C	33.0 mm Hg
Viscosity at 20°C	2.4 cps.
Water content	0.5% by wt, max.
Weight per gallon at 20°C	6.55 lb
60°F	6.58 lb

Table 6.62: Physical Properties of 91% Isopropyl Alcohol *(31)*

Acidity, as acetic acid	0.0024% by wt, max.
Color, Pt-Co scale	15 max.
Distillation at 760 mm	Distills entirely within a 1.0°C range which includes 80.4°C
Fire hazard	Dangerous when exposed to heat or open flame
Flash point (open cup)	75°F
Non-volatile matter	0.005 g/100 ml, max.
Odor	Non-residual
Permanganate time	30 minutes, minimum, at 15°C when using the Barbet end point
Purity	91.09% by volume, minimum, at 15.56°C.
Specific gravity at 20/20°C	0.8175 - 0.8185
Toxicity	Moderate by ingestion; otherwise slight
Water content	9% by volume, max.
Weight per gallon at 20°C	6.81 lb
60°F	6.84 lb

Table 6.63: Specific Gravity of Isopropyl Alcohol-Water Mixtures *(8)*

Specific Gravity	20/20°C % Vol.	20/20°C % Wt.
1.000	0.0	0.0
0.9990	0.8	0.6
0.9980	1.6	1.3
0.9970	2.4	1.9
0.9960	3.2	2.6
0.9950	4.0	3.3
0.9940	4.8	3.9
0.9930	5.6	4.5
0.9920	6.5	5.2
0.9910	7.3	5.8
0.9900	8.1	6.5
0.9890	8.9	7.1
0.9880	9.8	7.8
0.9870	10.6	8.4
0.9860	11.5	9.1
0.9850	12.3	9.8
0.9840	13.2	10.5
0.9830	14.0	11.2
0.9820	14.9	11.9
0.9810	15.7	12.6
0.9800	16.6	13.3
0.9790	17.4	14.1
0.9780	18.3	14.8
0.9770	19.1	15.5
0.9760	19.9	16.2
0.9750	20.8	16.9
0.9740	21.7	17.5
0.9730	22.5	18.2
0.9720	23.4	18.8
0.9710	24.2	19.4
0.9700	25.1	20.1
0.9690	25.8	20.7
0.9680	26.6	21.3
0.9670	27.3	22.0
0.9660	28.0	22.6
0.9650	28.7	23.2
0.9640	29.4	23.8
0.9630	30.1	24.4
0.9620	30.8	25.0
0.9610	31.4	25.6
0.9600	32.1	26.2
0.9590	32.7	26.7
0.9580	33.3	27.2
0.9570	33.9	27.7
0.9560	34.5	28.2
0.9550	35.1	28.7
0.9540	35.7	29.2
0.9530	36.3	29.7
0.9520	36.8	30.3
0.9510	37.4	30.8
0.9500	38.0	31.3
0.9490	38.5	31.8
0.9480	39.0	32.3
0.9470	39.6	32.8
0.9460	40.1	33.3
0.9450	40.6	33.8
0.9440	41.1	34.3
0.9430	41.6	34.8
0.9420	42.1	35.2
0.9410	42.7	35.7
0.9400	43.2	36.1
0.9390	43.7	36.6
0.9380	44.2	37.0
0.9370	44.7	37.5
0.9360	45.2	38.0
0.9350	45.6	38.4
0.9340	46.1	38.8
0.9330	46.6	39.3
0.9320	47.1	39.7
0.9310	47.5	40.2
0.9300	48.0	40.6
0.9290	48.5	41.1
0.9280	48.9	41.5
0.9270	49.4	42.0
0.9260	49.8	42.4
0.9250	50.3	42.9
0.9240	50.7	43.3
0.9230	51.2	43.7
0.9220	51.6	44.2
0.9210	52.0	44.6
0.9200	52.5	45.0
0.9190	52.9	45.5
0.9180	53.4	45.9
0.9170	53.8	46.3
0.9160	54.2	46.7
0.9150	54.7	47.2
0.9140	55.1	47.6
0.9130	55.5	48.0
0.9120	56.0	48.5
0.9110	56.4	48.9
0.9100	56.4	48.9
0.9090	57.3	49.7
0.9080	57.7	50.2
0.9070	58.1	50.6
0.9060	58.6	51.0
0.9050	59.0	51.4
0.9040	59.4	51.8
0.9030	59.8	52.3
0.9020	60.3	52.7
0.9010	60.7	53.1
0.9000	61.1	53.5
0.8990	61.5	53.9
0.8980	62.0	54.4
0.8970	62.4	54.8
0.8960	62.8	55.2
0.8950	63.2	55.6
0.8940	63.6	56.0
0.8930	64.1	56.5
0.8920	64.5	56.9
0.8910	64.9	57.3
0.8900	65.3	57.7
0.8890	65.7	58.1
0.8880	66.1	58.6
0.8870	66.5	59.0
0.8860	66.9	59.4
0.8850	67.3	59.8
0.8840	67.7	60.2
0.8830	68.0	60.7
0.8820	68.4	61.1
0.8810	68.8	61.5
0.8800	69.2	61.9
0.8790	69.6	62.3
0.8780	69.9	62.8
0.8770	70.3	63.2
0.8760	70.7	63.6
0.8750	71.1	64.0
0.8740	71.4	64.4
0.8730	71.8	64.9
0.8720	72.2	65.3
0.8710	72.6	65.7
0.8700	72.9	66.1
0.8690	73.3	66.5
0.8680	73.7	67.0
0.8670	74.0	67.4
0.8660	74.4	67.8
0.8650	74.8	68.2
0.8640	75.2	68.6
0.8630	75.5	69.1
0.8620	75.9	69.5
0.8610	76.3	69.9
0.8600	76.6	70.3
0.8590	77.00	70.75
0.8580	77.36	71.17
0.8570	77.72	71.59
0.8560	78.08	72.01
0.8550	78.44	72.43
0.8540	78.80	72.85
0.8530	79.16	73.27
0.8520	79.52	73.69
0.8510	79.88	74.11
0.8500	80.24	74.54
0.8490	80.60	74.95
0.8480	80.96	75.37
0.8470	81.32	75.79
0.8460	81.68	76.21
0.8450	82.04	76.63
0.8440	82.40	77.04
0.8430	82.76	77.45
0.8420	83.12	77.86
0.8410	83.48	78.27
0.8400	83.84	78.68
0.8390	84.20	79.09
0.8380	84.55	79.50
0.8370	84.90	79.91
0.8360	85.25	80.32
0.8350	85.60	80.73
0.8340	85.95	81.14
0.8330	86.30	81.55
0.8320	86.65	81.96
0.8310	87.00	82.37
0.8300	87.33	82.78
0.8290	87.69	83.19
0.8280	88.03	83.60
0.8270	88.36	84.01
0.8260	88.69	84.42
0.8250	89.02	84.83
0.8240	89.35	85.24
0.8230	89.68	85.65
0.8220	90.01	86.06
0.8210	90.34	86.47
0.8200	90.67	86.88
0.8190	91.00	87.29
0.8180	91.32	87.70
0.8170	91.63	88.10
0.8160	91.93	88.50
0.8150	92.23	88.90
0.8140	92.53	89.30
0.8130	92.83	89.70
0.8120	93.13	90.10
0.8110	93.43	90.50
0.8100	93.72	90.90
0.8090	94.01	91.30
0.8080	94.30	91.70
0.8070	94.58	92.10
0.8060	94.86	92.49
0.8050	95.14	92.88
0.8040	95.42	93.27
0.8030	95.69	93.66
0.8020	95.96	94.04
0.8010	96.23	94.42
0.8000	96.50	94.80
0.7990	96.77	95.18
0.7980	97.04	95.56
0.7970	97.31	95.94
0.7960	97.57	96.32
0.7950	97.83	96.70
0.7940	98.08	97.08
0.7930	98.33	97.46
0.7920	98.58	97.84
0.7910	98.83	98.22
0.7900	99.08	98.60
0.7890	99.33	98.98
0.7880	99.58	99.36
0.7870	99.83	99.74
0.7863	100.00	100.00

Gravity-temperature coefficient of 100 % alcohol 20-22 - .00086/°C

Table 6.64: Vapor-Liquid Compositions of Isopropyl Alcohol-Water Mixtures and Their Boiling Points *(8)*

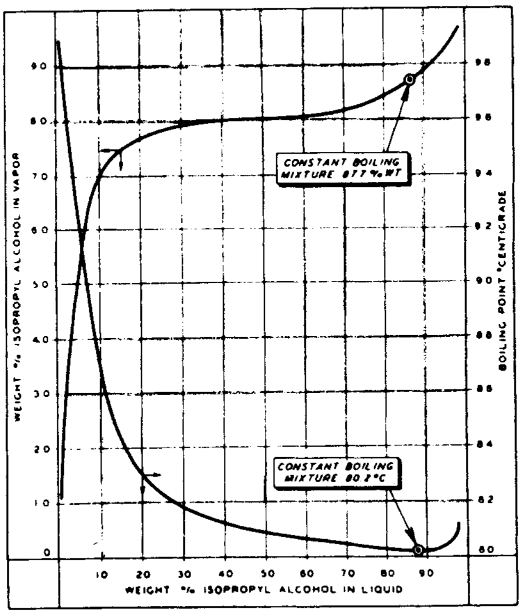


Table 6.65: Refractive Index vs Composition of Isopropyl Alcohol-Water Mixtures at 25°C *(19)*

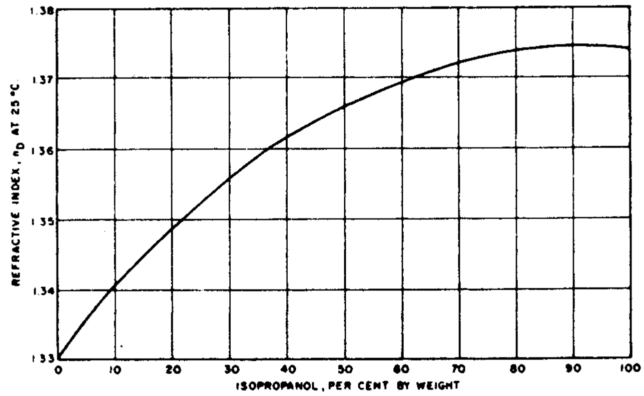


Table 6.66: Isopropyl Alcohol-Water: Kinematic Viscosity vs Composition at 25°C *(19)*

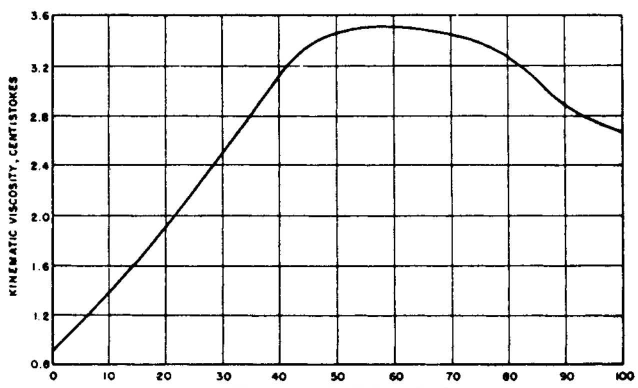


Table 6.67: Azeotropes of Isopropyl Alcohol *(31)*

ISOPROPYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
56	Acrylonitrile	71.7
66.7	Benzene	71.9
66	2-Bromobutane	77.5
68	2-Butanone	77.9
40	n-Butylamine	84.7
28.1	Butyl isopropyl ether	79.0
92	Carbon disulfide	44.6
82	Carbon tetrachloride	67.0
77	1-Chlorobutane	70.8
82	2-Chlorobutane	64.0
57	1-Chloro-3-methylbutane	79.2
64	1,3-Cyclohexadiene	70.4
67	Cyclohexane	68.6
73	Cyclohexene	70.5
48	Diethoxymethane	79.6
45.5	Diisobutylene	77.8
91	2,3-Dimethylbutane	53.8
22	1,3-Dimethylcyclohexane	81.0
38	2,5-Dimethylhexane	79.0
74	Ethyl acetate	74.0
90	Ethyl propyl ether	62.0
48	Ethyl sulfide	78.0
60.8	Ethylene dichloride	72.7
70	Fluorobenzene	74.5
49.5	n-Heptane	76.4
77	Hexane	62.7
30	1-Iodo-2-methylpropane	81.5
81	Isobutyl chloride	63.8
47.7	Isopropyl acetate	80.1
83.7	Isopropyl ether	66.2
53.5	Methyl acrylate	76.0
47	Methylcyclohexane	77.6
75	Methylcyclopentane	63.3
70	Methyl ethyl ketone	77.3
35	Methyl isobutyrate	81.4
62	Methyl propionate	76.4
16	Octane	81.8
94	Pentane	35.5
48	Propyl ether	78.2
64	Propyl formate	76.9
19	Tetrachloroethylene	81.7
57	Thiophene	76.0
31	Toluene	80.6
72	Trichloroethylene	74.0
77.6	Vinyl acetate	70.8
12.2	Water	79.5

ISOPROPYL ALCOHOL FORMS TERNARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
7.5 73.8	Water Benzene	66.5
7.5 74	Water Cyclohexane	64.8
7.5 71	Water Cyclohexene	61.1
10 9.3	Water Diisobutylene	72.3
10.4 67.7	Water Ethyl butyl ether	73.4
7.7 73.3	Water Ethylene dichloride	69.7
11 76	Water Isopropyl acetate	75.5
4.7 88	Water Isopropyl ether	61.6
6 32	Water Nitromethane	78.0
13.1 48.7	Water Toluene	76.3

Table 6.68: The Effect of Isopropyl Alcohol on the Dilution Ratio of Solvents *(14)*

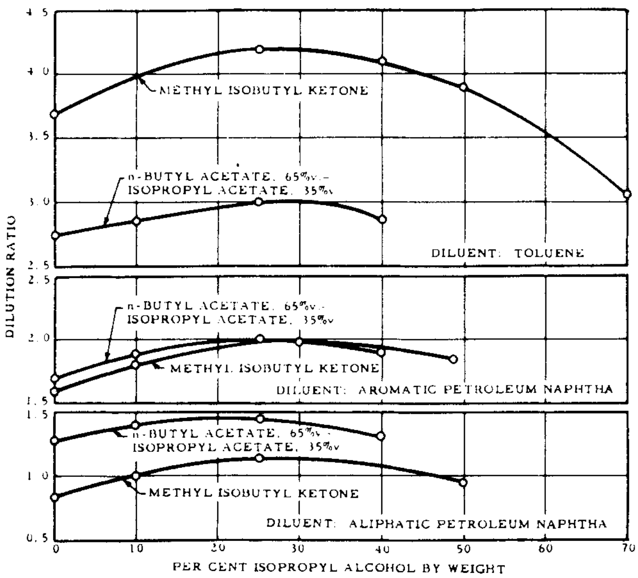


Table 6.69: Viscosity of RS ½ Sec. Nitrocellulose in Mixtures of Toluene, Isopropyl Alcohol and Methyl Isobutyl Ketone *(14)*

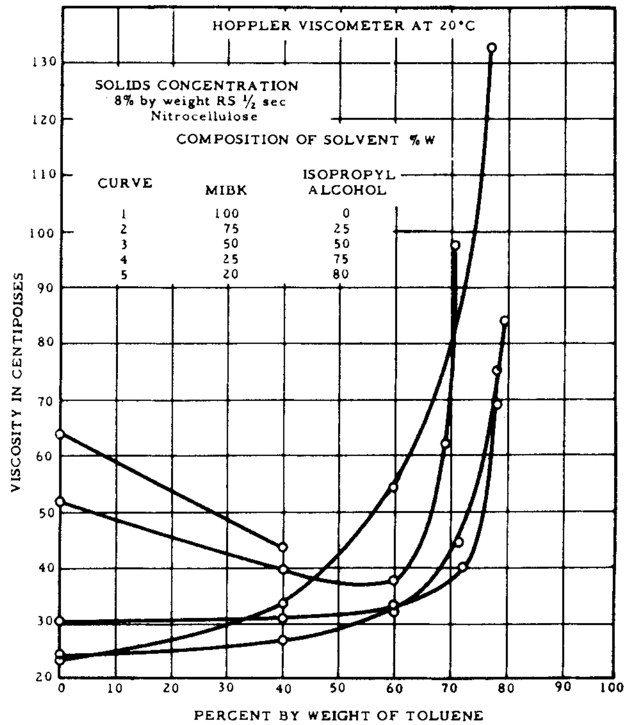


Table 6.70: Methanol-Isopropyl Alcohol: Boiling Point vs Composition at 760 mm Hg *(19)*

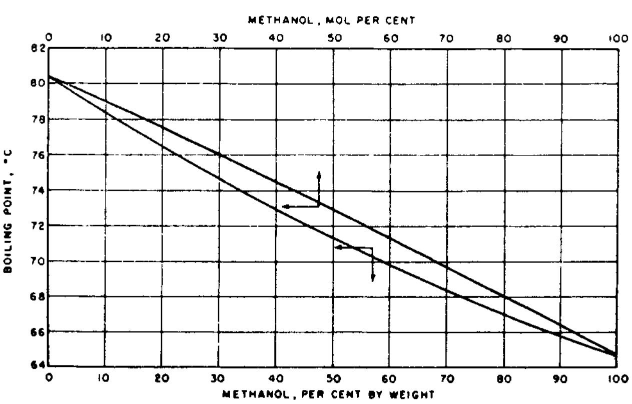
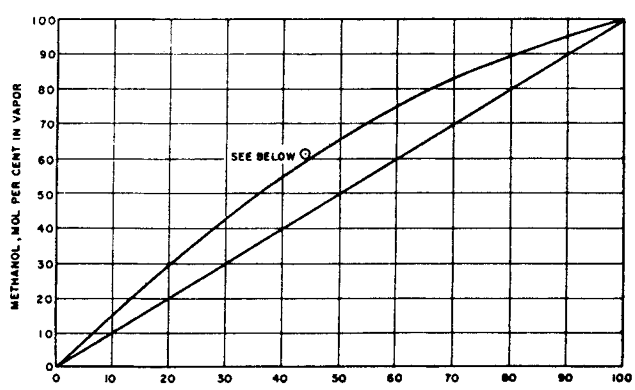


Table 6.71: Methanol-Isopropyl Alcohol:Liquid-Vapor Equilibria at Atmospheric Pressure *(19)*



Composition at 200 mm. Hg: 43.9 mol per cent in liquid, 60.9 mol per cent in vapor. Isopropanol-Water azeotrope contains 68.3 mol per cent isopropanol.

Table 6.72: Vapor Pressure of Isopropyl Alcohol (Anhydrous) and sec-Butyl Alcohol at Various Temperatures *(8)*

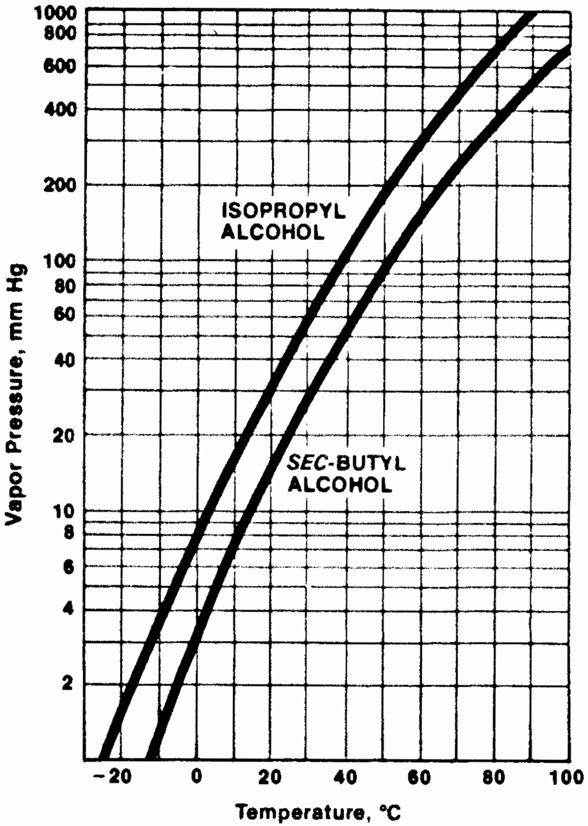
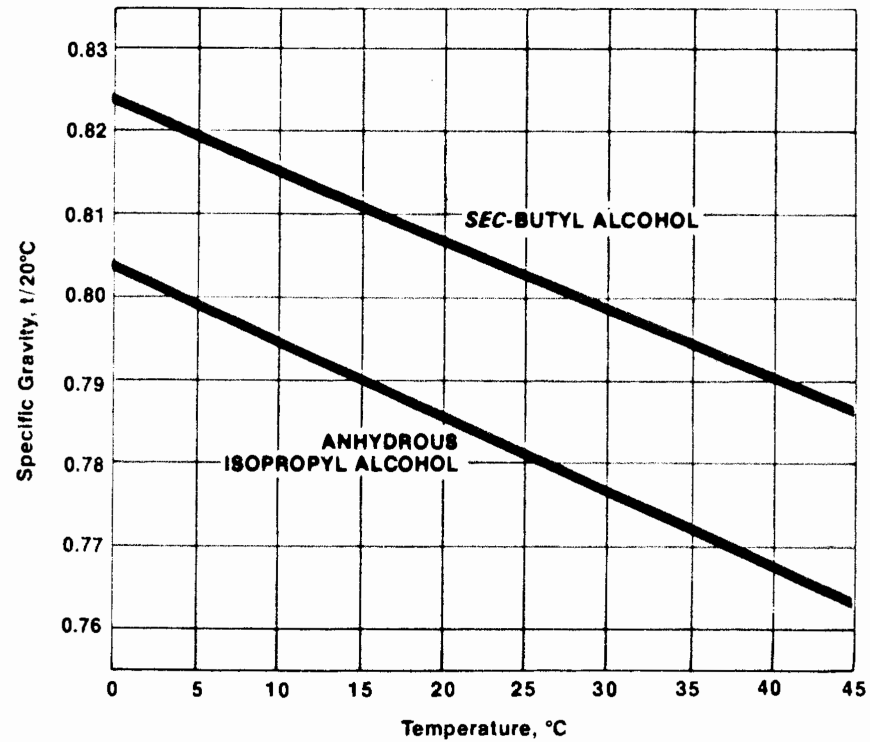


Table 6.73: Specific Gravities of Alcohols vs Temperature *(8)*



n-BUTYL ALCOHOL

n-Butanol, Butanol-1, Butyric Alcohol $CH_3CH_2CH_2CH_2OH$

Table 6.74: Physical Properties of n-Butyl Alcohol *(31)*

PHYSICAL PROPERTIES OF n-BUTYL ALCOHOL

Acidity as acetic acid	0.005% by wt, max.
Aldehydes	None
Boiling point at 760 mm	117.7°C
Chlorides	None
Coefficient of cubical expansion per °C	0.00093
per °F	0.00052
Color, Pt-Co	10 max.
Critical pressure	48.4 atm
Critical temperature	287°C
Dielectric constant at 25°C	16.1
Distillation range (including 117.7°C)	1.5°C max.
Electrical conductivity at 25°C	9.12 x 10^{-9} reciprocal ohms
Explosive limits in air, Lower	1.45% by vol.
Upper	11.25% by vol.
Fire hazard	Moderate
Flash point, Tag open cup	115°F
Freezing point	-89.0°C
Heat of combustion	8626 cal/g
Heat of fusion	29.9 cal/g
Heat of vaporization at boiling point	141.3 cal/g
Ignition temperature	367°C
Iron	None
MAC	100 ppm in air
Melting point	-89.8°C
Molecular weight	74.12 calculated
Non-volatile matter	0.005 g/100 ml, max.
Odor	Characteristic, non-residual
Refractive index at 20°C, n_D	1.3992
Relative evaporation rate, n-butyl acetate = 1	0.45
Solubility in water at 20°C	7.8% by wt
Solubility of water in n-Butanol at 20°C	20.1% by wt
Specific gravity at 20/20°C	0.8109
Specific heat of liquid at 20°C	0.563 cal/g
Sulfuric acid test (Pt-Co)	25 max.
Surface tension at 20°C	24.6 dynes/cm
Suspended matter	Substantially free
Toxicity	Moderately toxic by inhalation, ingestion and skin absorption
Vapor pressure at 20°C	4.39 mm Hg
40°C	18.6 mm Hg
60°C	59.2 mm Hg
75°C	131.3 mm Hg
100.8°C	400.0 mm Hg
Viscosity at 20°C	2.948 centipoises
Water content	0.10% by wt, max.
Weight per gallon at 20°C	6.756 lbs

Table 6.75: Vapor Pressure of Butyl Alcohol at Various Temperatures *(19)*

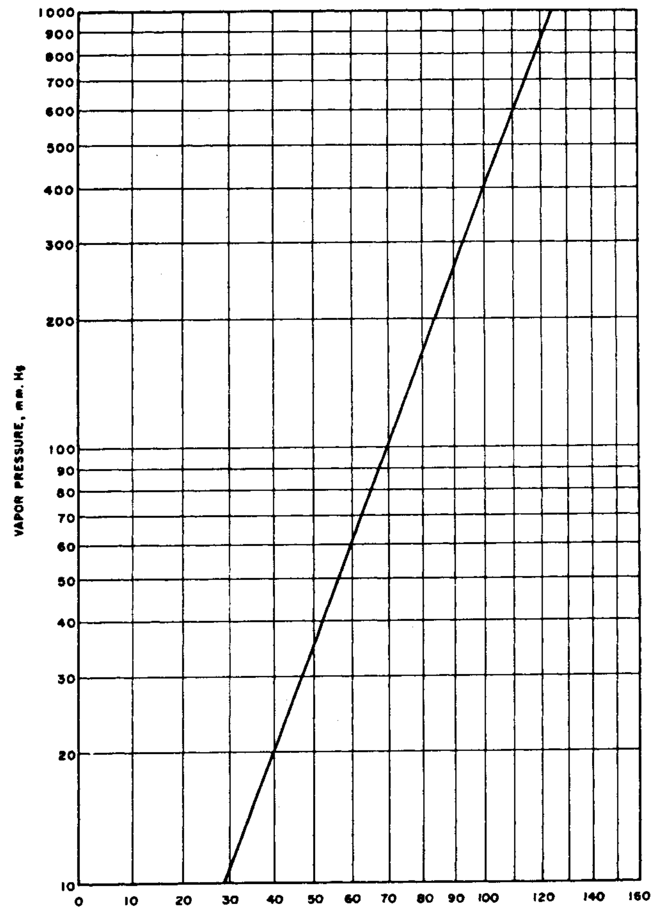


Table 6.76: Solubility of Water in Butyl Alcohol at Various Temperatures *(19)*

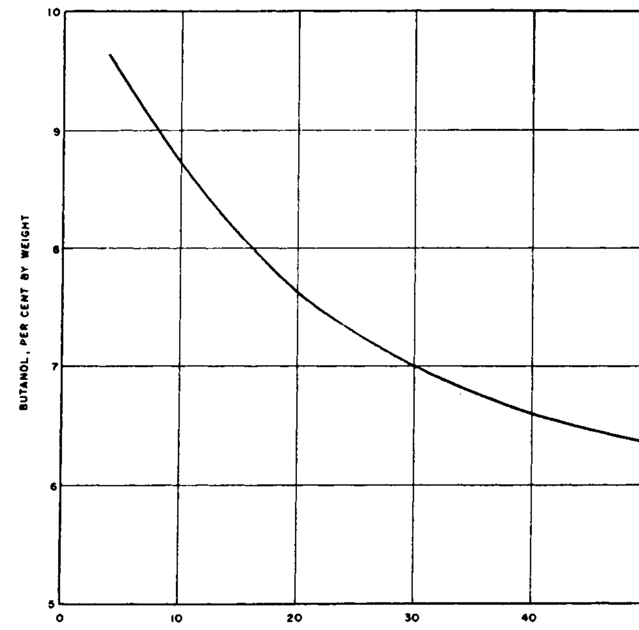


Table 6.77: Solubility of Butyl Alcohol in Water at Various Temperatures *(19)*

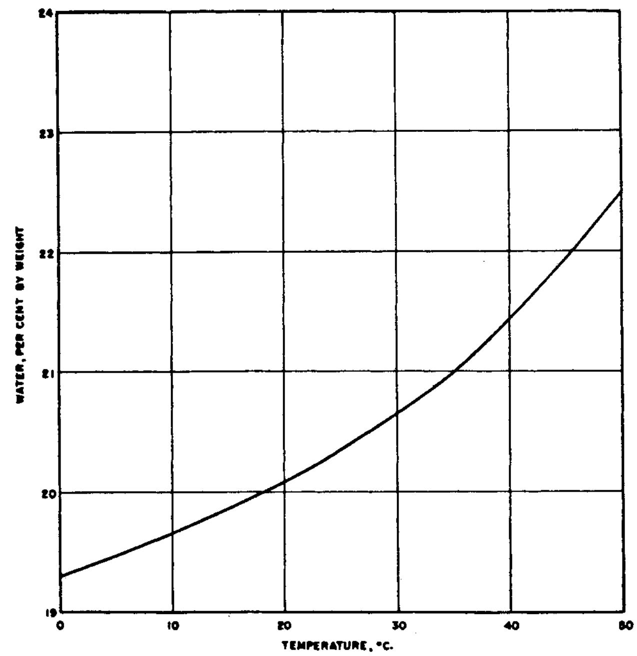


Table 6.78: Azeotropes of n-Butyl Alcohol *(31)*

n-BUTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
87	Acetal	101.0
68.5	1-Bromo-3-methylbutane	110.7
32.8	Butyl acetate	117.6
12	Butyl ether	117.3
76.4	Butyl formate	105.8
92.2	Butyl vinyl ether	93.3
2	Camphene	117.8
44	Chlorobenzene	115.3
88	1-Chloro-3-methylbutane	97.0
90	Cyclohexane	79.8
95	Cyclohexene	82.0
17.5	Dibutyl ether	117.6
57	1,3-Dimethylcyclohexane	108.5
72	2,5-Dimethylhexane	101.9
48	Ethyl borate	113.0
36	Ethyl butyrate	115.7
37	Ethyl carbonate	116.5
83	Ethyl isobutyrate	109.2
82	Heptane	93.3
97	Hexane	67.0
18.2	2-Hexanone	116.5
20	3-Hexanone	117.2
22	1-Iodo-3-methylbutane	117.3
31	Isoamyl formate	115.9
50	Isobutyl acetate	114.5
52	Isobutyl ether	113.5
46	Isopropyl isobutyrate	115.5
55	Isopropyl sulfide	112.0
86	Methylcyclohexane	95.3
92	Methylcyclopentane	71.8
60	Methyl isovalerate	116.3
70	4-Methyl-2-pentanone	114.4
50	Octane	110.2
48	Paraldehyde	115.8
12	α-Pinene	117.4
29	Pyridine	118.7
21	Styrene	116.5
68	Tetrachloroethylene	110.0
73	Toluene	105.6
25	o-Xylene	116.8
32	p-Xylene	115.7

n-BUTYL ALCOHOL FORMS TERNARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
37.3	Water	89.4
35.3	Butyl acetate	
41.8	Water	93.1
7.9	Butyl chloroacetate	
29.3	Water	91.0
27.7	Butyl ether	
21.3	Water	83.6
68.7	Butyl formate	
3.1	Water	64.7
85.0	Carbon tetrachloride	

ISOBUTYL ALCOHOL

Isobutanol, 2-Methyl Propanol-1, Isopropyl Carbinol $(CH_3)_2CHCH_2OH$

Table 6.79: Physical Properties of Isobutyl Alcohol *(31)*

Alkalinity	0.003% by wt, max.
Boiling point at 760 mm	107.9°C
Coefficient of cubical expansion at 10 to 30°C	0.95×10^{-3}
Color, APHA	10 max.
Critical pressure	48 atm
Critical temperature	265°C
Distillation range (including 107.9°C)	2°C max.
Electrical conductivity at 25°C	8×10^{-3} mho per cm.
Evaporation rate (n-Butyl Acetate = 1.0)	0.8
Explosive limits in air, lower limit	1.68% by volume
Fire hazard	Moderate
Flash point, Tag open cup	103°F
Heat of combustion	6382 cal/g
Heat of vaporization at boiling point	138 cal/g/mole
Ignition temperature	440°C
Melting point	-108°C
Molecular weight	74.12 calculated
Non-volatile matter	0.001 g/100 ml, max.
Refractive index at 20°C, n_D	1.3959
Solubility in water at 25°C	8.8 ml per 100 ml
Solubility of water in isobutyl alcohol at 25°C	20.0 ml per 100 ml
Specific gravity at 20/20°C	0.8034
Specific heat at 15°C	0.716 cal/g/°C
Surface tension at 20°C	22.8 dynes/cm
Toxicity	Highly toxic by inhalation or ingestion
Vapor density (Air = 1.0)	2.55
Vapor pressure at 20°C	8.8 mm
Viscosity at 20°C	6.68 centipoises
Water content	0.2% by wt, max.
Weight per gallon at 20°C	6.68 lbs

Table 6.80: Azeotropes of Isobutyl Alcohol *(31)*

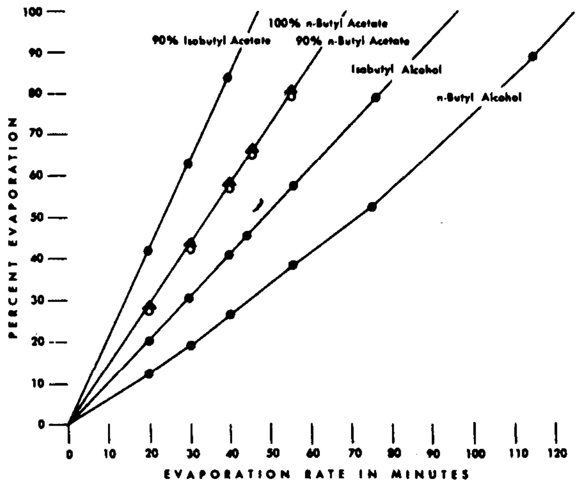
ISOBUTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
90.7	Benzene	79.9
36.4	1-Bromo-3-methylbutane	103.4
60	Butyl formate	103.0
37	Chlorobenzene	107.1
78	1-Chloro-3-methylbutane	94.5
88	1,3-Cyclohexadiene	79.4
86	Cyclohexane	78.1
85.8	Cyclohexene	80.5
44	1,3-Dimethylcyclohexane	102.2
48	Ethyl isobutyrate	105.5
87	Ethyl propionate	98.9
91	Fluorobenzene	84.0
73	Heptane	90.8
97.5	Hexane	68.3
45	Isobutyl acetate	107.4
79.4	Isobutyl formate	97.8
93.8	Isobutyl vinyl ether	82.7
27	Isopropyl sulfide	105.8
75	Methyl butyrate	101.3
68	Methylcyclohexane	92.6
95	Methylcyclopentane	71.0
10	Methyl isovalerate	107.5
9	4-Methyl-2-pentanone	107.9
81	2-Pentanone	101.8
80	3-Pentanone	101.7
68	Pinacolone	105.5
83	Propyl acetate	101.0
90	Propyl ether	89.5
55	Toluene	101.2
73	2,2,4-Trimethylpentane	92.0

ISOBUTYL ALCOHOL FORMS TERNARY AZEOTROPES WITH:

30.4	Water	86.8
46.5	Isobutyl acetate	
33.6	Water	90.2
13.3	Isobutyl chloroacetate	
17.3	Water	80.2
76	Isobutyl formate	

Table 6.81: Relative Evaporation Rates of Various Butyl Alcohols and Acetates *(41)*



sec-BUTYL ALCOHOL

sec-Butanol, Butanol-2, Methyl Ethyl Carbinol

$CH_3CHOHCH_2CH_3$

Table 6.82: Physical Properties of sec-Butyl Alcohol *(31)*

Acidity as acetic acid	0.003% by wt, max.
Boiling point at 760 mm	99.5°C
Coefficient of cubical expansion at 20°C	0.00101°C
Color, Pt-Co (Hazen)	10 max.
Critical pressure	46.9 atm
Critical temperature	265.19°C
Distillation range	98.0-101.0°C
Fire hazard	Dangerous when exposed to heat or flame
Flash Point, Tag open cup	80°F
Tag closed cup	75°F
Freezing point	-114.7°C
Heat of vaporization at 1 atm.	134.4 g cal/g
Molecular weight	74.12
Non-volatile matter	0.002 ml, max.
Purity	99.0% min.
Refractive index at 20°C n_D	1.39719
Relative evaporation rate, n-Butyl acetate = 100	120
Solubility in water at 20°C	22.5% by wt
Solubility of water in, at 20°C	60.0% by wt
Specific gravity at 20/20°C	0.8079
Specific heat at 8.5°C	0.596
Surface tension at 20°C	23.0 dynes/cm
Toxicity	Moderate
Vapor pressure at 20°C	12.1 mm
Viscosity at 20°C	3.78 cps.
Water, presence of	Miscible without turbidity with 19 vol. of n-heptane at 20°C
Weight per gallon at 20°C	6.73 lb

Table 6.83: Azeotropes of sec-Butyl Alcohol *(31)*

sec-BUTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
61	tert-Amyl ethyl ether	94.5
93	tert-Amyl methyl ether	86.0
84.6	Benzene	78.6
13.7	sec-Butyl acetate	99.6
32	Butyl formate	98.0
71	1-Chloro-3-methylbutane	91.5
79	Cyclohexene	78.7
46	2,5-Dimethylhexene	93.0
53	Ethyl propionate	95.7
68	Ethyl sulfide	89.0
62	Heptane	89.0
92	Hexane	67.2
60	Isobutyl formate	94.7
41	Methyl butyrate	97.7
59	Methylcyclohexane	89.9
88.5	Methylcyclopentane	69.7
77	Methyl isobutyrate	92.0
42	3-Pentanone	98.0
16	Pinacolone	99.1
48	Propyl acetate	96.5
78	Propyl ether	87.0
45	Toluene	95.3

tert-BUTYL ALCOHOL

tert-Butanol, 2-Methyl Propanol-2 $(CH_3)_3COH$

Table 6.84: Physical Properties of tert-Butyl Alcohol *(31)*

Acidity as acetic acid	0.003% by wt, max.
Boiling point at 760 mm	82.36°C
Coefficient of cubical expansion at 26°C	0.00132°C
Color, Pt-Co (Hazen) max.	10 max.
Compressibility at 20°C, between 100-500 megabars	79.6×10^{-6} megadynes/cm
Critical pressure	46 atm
Critical temperature	234.9°C
Dielectric constant at 19°C (audio)	11.4 cgs units
Distillation range	81.5-83.0°C
Dipole moment	1.65×10^{18}
Fire hazard	Dangerous when exposed to heat or flame
Flash point, Tag open cup	60°F (approx.)
Tag closed cup	48°F (approx.)
Freezing point	25.57°C
Heat of combustion	
Liquid at constant volume	6290 cal/g
constant pressure	6302 cal/g
Vapor at constant pressure	6426 cal/g
Heat of fusion at 25.5°C	21.88 cal/g
Heat of solution at 15°C, of the solid alcohol in water	3.23 kg cal
Heat of vaporization at 1 atm.	130.6 g cal/g
Melting point	25.57°C
Molecular weight	74.12
Molecular volume, $20/V_M$	94.3 cc
Non-volatile matter	0.002 g/100 ml, max.
Purity	99.0% by wt, min.
Refractive index at 20°C, n_D	1.3841
Solubility at 20°C, in water	Complete
water in	Complete
Specific heat at 26°C	0.726 g cal/g
Specific gravity at 26/4°C	0.7793
Surface tension at 20°C	20.7 dynes
34.5°C	19.45 dynes
80°C	14.6 dynes
Toxicity	Moderate
Vapor pressure at 30°C	57.3 mm
Viscosity at 30°C	3.316 cps.
Water	Miscible without turbidity with 19 vol. of n-heptane at 20°C
Weight per gallon at 26°C	6.50 lb

Table 6.85: Azeotropes of tert-Butyl Alcohol *(31)*

tert-BUTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
63.4	Benzene	74.0
94	Carbon disulfide	45.7
76	Carbon tetrachloride	29.5
41	1-Chloro-3-methylbutane	81.2
61.5	1,3-Cyclohexadiene	73.4
63	Cyclohexane	71.3
60	Cyclohexene	73.2
93	Cyclopentane	48.2
65	Dibromodichloromethane	79.0
94	1,1-Dichloroethane	57.1
33	Diisobutyl alcohol	81.5
87	2,3-Dimethylbutane	55.3
10	1,3-Dimethylcyclohexane	82.2
23	2,5-Dimethylhexane	81.5
75	Ethyl acetate	76.0
38	Ethyl nitrate	78.0
30	Ethyl sulfide	79.8
69	Fluorobenzene	76.0
38	Heptane	78.0
78	Hexane	63.7
83	Isobutyl chloride	65.5
34	Methylcyclohexane	78.8
74	Methylcyclopentane	66.6
70	Methylcyclopentene	69.5

PRIMARY AMYL ALCOHOL

Primary amyl alcohol, a mixture of isomers all of which are primary alcohols, is composed of approximately 60% pentanol-1 ($CH_3CH_2CH_2CH_2CH_2OH$); 35% 2-methyl butanol-1 ($CH_3CH_2CH(CH_3)CH_2OH$); and 5% 3-methyl butanol-1 ($CH_3CH(CH_3)CH_2CH_2OH$).

Table 6.86: Physical Properties of Primary Amyl Alcohol *(19)*

Acidity as acetic acid	0.01% by wt, max.
Boiling point at 760 mm	133.1°C
50 mm	68°C
10 mm	39°C
Carbonyl, as C_5 aldehyde	0.20% by wt, max.
Coefficient of expansion at 20°C	0.00092 per °C
Color, Pt-Co	15, max.
Distillation at 760 mm Ibp	127.5°C
Dp	139.0°C, max.
Fire hazard	Moderate
Flash point (open cup)	118°F
Freezing point	Sets to glass below -90°C
Heat of vaporization at 133°C	242 Btu/lb
Purity, as primary amyl alcohols	98.0% by wt, min.
Refractive index at 20°C, n_D	1.4084
Solubility in water at 20°C	1.7% by wt
Solubility of water in, at 20°C	9.2% by wt
Specific gravity at 20/20°C	0.8134

PRIMARY n-AMYL ALCOHOL

Table 6.87: Physical Properties of Primary n-Amyl Alcohol *(31)*

Acidity (mg KOH/g)	0.06 max.
Boiling point	137.8°C
Clarity	No turbidity or suspended matter
Coefficient of expansion per °C	0.00092
Distillation, initial	Not below 134.8°C
final	Not above 140.0°C
Fire point	140°F
Fire hazard	Moderate
Flash point (open cup)	135°F
Heat of vaporization	120.6 cal/g (calculated)
Melting point	-78.5°C
Molecular weight	88.15 (calculated)
Non-volatile matter at 100°C	5.0 mg/100 ml, max.
Refractive index at 20°C	1.4099
Specific gravity at 20/20°C	0.82
Specific heat	0.712 cal/g
Toxicity	Highly toxic by inhalation and ingestion
Viscosity at 25°C	3.31 centipoises
60°C	1.33 centipoises
Weight per gallon	6.82 lbs

sec-AMYL ALCOHOL

Table 6.88: Physical Properties of sec-Amyl Alcohol *(31)*

Acidity as acetic acid	0.02% max.
Boiling point	119.3°C
Coefficient of expansion	
per 1°F	0.00053
1°C	0.00095
Distillation range	105° - 125°C
Evaporation rate at 90°F	
in minutes: 5%	2.25
25%	11.75
50%	24.25
75%	38.25
90%	50.25
95%	56.50
Flash point, Open cup	105°F
Fire hazard	Moderate
Heat of vaporization	97.8 cal/g (calculated)
Non-volatile at 100°C	0.003 g/100 cc max.
Purity	99% by wt, min.
Refractive index at 25°C, n_D	1.4041
Solubility of water in	8.2% by vol.
Specific gravity at 20°C	0.811
Toxicity	Highly toxic by ingestion and inhalation
Weight per gallon at 20°C	6.75 lbs

Table 6.89: Azeotropes of sec-Amyl Alcohol *(31)*

sec-AMYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
45	Chlorobenzene	118.2
62	1,3-Dimethylcyclohexane	113.0
33	Ethylbenzene	118.0
53	Ethyl butyrate	118.5
85	Heptane	96.0
68	Isobutyl acetate	116.5
59	Isobutyl ether	115.0
82	Methylcyclohexane	98.6
80	Methyl isovalerate	115.8
44	Octane	114.8
72	Toluene	107.0
30	m-Xylene	118.3

sec-n-AMYL ALCOHOL

Table 6.90: Physical Properties of sec-n-Amyl Alcohol *(31)*

Acidity as acetic acid	0.06% max.
Boiling point	115.6°C
Coefficient of expansion per °C	0.00149
Distillation, 95%	Between 113.6 - 117.6°C
Fire hazard	Moderate
Flash point	100°F
Freezing point	Less than -75°C
Heat of vaporization	96.8 cal/g (calculated)
Non-volatile at 100°C	0.003 g/100 cc max.
Refractive index at 20°C	1.4098
Specific gravity at 20°C	0.82
Toxicity	Highly toxic by inhalation and ingestion
Viscosity at 25°C	4.12 centipoises
60°C	1.09 centipoises
Weight per gallon at 20°C	6.81 lbs

Table 6.91: Azeotropes of sec-n-Amyl Alcohol *(31)*

sec-n-AMYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
97	Cyclohexane	80.0
80	Heptane	96.0
77	Methylcyclohexane	97.4
65	4-Methyl-2-pentanone	115.0
65	Toluene	106.0

tert-AMYL ALCOHOL, REFINED

2-Methyl Butanol-2, Dimethylethyl Carbinol, Amylene Hydrate, tert-Pentanol $(CH_3)_2COHCH_2CH_3$

Table 6.92: Physical Properties of Refined tert-Amyl Alcohol *(31)*

Acidity as acetic acid	0.15% max.
Boiling point	101.8°C
Clarity	No turbidity or suspended matter
Coefficient of expansion per °C	0.00133 (calculated)
Distillation, 95% between	98.8 - 103.8°C
Fire hazard	Dangerous when exposed to heat or flame
Flash point, Open cup	70°F
Freezing point	-11.9°C
Heat of vaporization	93.4 cal/g
Molecular weight	88.15 (calculated)
Neutralization value, mg KOH/g	0.06 max.
Non-volatile matter	0.003 g/100 cc, max.
Odor	Camphor-like
Refractive index at 20°C	1.4052
Specific gravity at 20/20°C	0.81 - 0.82
Specific heat	0.753 cal/g
Toxicity	Moderate
Viscosity at 25°C at 63°C	3.70 centipoises 0.99 centipoises
Water content	None
Water tolerance, water per 100 cc alcohol	18.0 min.
Weight per gallon	6.75 lbs

Table 6.93: Azeotropes of tert-Amyl Alcohol *(31)*

tert-AMYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
85	Benzene	80.0
85	1,3-Cyclohexadiene	79.7
84	Cyclohexane	78.5
83	Cyclohexene	80.8
32	1,3-Dimethylcyclohexane	101.1
50	2,5-Dimethylhexane	97.0
73.5	Heptane	92.2
96	Hexane	68.3
60	Methylcyclohexane	92.0
95	Methylcyclopentane	71.5
25	Octane	101.1
80	Propyl ether	88.8
44	Toluene	100.5

ISOAMYL ALCOHOL

3-Methyl-1-Butanol, Primary Isoamyl Alcohol, Isobutyl Carbinol $(CH_3)_2CHCH_2CH_2OH$

Table 6.94: Physical Properties of Isoamyl Alcohol *(31)*

Acidity as acetic acid	0.01% max.
Boiling point at 760 mm	131.4°C
Coefficient of expansion per °C	0.00090
per °F	0.00050
Color, APHA	No. 10 max.
Critical temperature	307°C
Distillation range, below 128°C	None
above 132°C	None
Dryness	A 5 ml. sample is clearly miscible with at least 19 parts of 60 Bé gasoline at 60°F
Esters	Not more than 0.060% as amyl acetate
Fire hazard	Moderate
Flash point, Open cup	125°F
Heat of combustion	794.5 gram calories per gram
Latent heat of vaporization	105.4 gram calories per gram
MAC	100 ppm in air
Melting point	-117.2°C
Molecular weight	88.15
Non-volatile matter	0.003% max.
Odor	Alcoholic, non-residual
Refractive index at 20°C	1.4014
Solubility in water at 14°C	2.0% by wt
Specific gravity at 20/20°C	0.810 - 0.813
Specific heat at 20°C	0.544 gram calories per gram per °C
Surface tension at 20°C	23.8 dynes per cm
Toxicity	Highly toxic by ingestion and inhalation
Vapor pressure at 20°C	2.8 mm Hg
Viscosity (absolute) at 23.8°C	3.86 centipoises
Weight per gallon at 20°C	6.76 lbs approx.

Table 6.95: Azeotropes of Isoamyl Alcohol *(31)*

ISOAMYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
15	Bromobenzene	131.7
82.5	Butyl acetate	125.9
35	Butyl ether	129.8
76	Camphene	130.9
66	Chlorobenzene	124.4
6	Cumene	131.6
73	1,3-Dimethylcyclohexane	116.6
85	2,5-Dimethylhexane	107.6
42	Ethyl isovalerate	130.5
93	Heptane	97.7
2.6	Isoamyl acetate	129.1
74.5	Isoamyl formate	123.6
88	Isoamyl vinyl ether	112.1
78	Isobutyl ether	119.8
28	Isobutyl propionate	131.2
76	Mesityl oxide	129.2
87	Methylcyclohexane	98.2
65	Octane	120.0
78	Paraldehyde	123.5
26	α-Pinene	137.7
47	Propyl isobutyrate	130.2
21	Propyl sulfide	130.5
95	2,2,4-Trimethylpentane	99.0
48	o-, m-, or p-Xylene	125-126

ISOAMYL ALCOHOL FORMS TERNARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
44.8	Water	93.6
24.0	Isoamyl acetate	
46.2	Water	95.4
6.5	Isoamyl chloroacetate	
32.4	Water	89.8
48	Isoamyl formate	

ACTIVE AMYL ALCOHOL

Table 6.96: Physical Properties of Active Amyl Alcohol *(31)*

Acidity (mg KOH per g)	0.06 max.
Boiling point	128°C
Coefficient of expansion per °C	0.00078
Distillation: 95%	Between 125 - 131°C min.
30%	Above 130°C max.
Flash point, Open cup	120°F
Freezing point	Less than -70°C
Heat of vaporization	100.0 cal/g (calculated)
Refractive index at 20°C	1.4097
Residue	0.003 g/100 cc
Specific gravity at 20/4°C	0.816
Viscosity at 20°C	5.09 centipoises
60°C	1.44 centipoises
Weight per gallon at 20°C	6.80 lbs

FUSEL OIL, REFINED

Refined fusel oil is a volatile, poisonous, oily mixture consisting largely of amyl alcohols.

Table 6.97: Physical Properties of Refined Fusel Oil *(31)*

Acidity as acetic acid	0.01% max.
Coefficient of expansion per 1°C	0.00051-0.0006
1°F	0.00092-0.0011
Color, APHA	No. 10 max.
Distillation range (ASTM) below 110°C	None
below 120°C	Not more than 15%
below 130°C	Not less than 60%
above 135°C	None
Dryness	A 5 ml. sample is clearly miscible with at least 19 parts of 60° Bé gasoline at 60°F
Evaporation rate at 95°F	% / Minutes
	5 / 3.5
	25 / 17.0
	50 / 36.5
	75 / 64.75
	90 / 90.25
	95 / 103.5
Fire hazard	Moderate
Flash point, Open cup	123°F, approx.
Closed cup	106°F, approx.
Specific gravity at 20/20°C	0.810-0.815
Toxicity	Highly toxic by ingestion and inhalation
Water solubility at 25°C, 100 cc solvent dissolves	9.9 cc water
Weight per gallon at 20°C	6.76 - 6.77 lbs

METHYLAMYL ALCOHOL

Methyl Isobutyl Carbinol, 4-Methylpentanol-2, MIBC $(CH_3)_2CHCH_2CHOHCH_3$

Methylamyl alcohol is a secondary alcohol.

Table 6.98: Physical Properties of Methylamyl Alcohol *(31)*

Acidity as acetic acid	0.005% by wt. max.	Heat of vaporization at 1 atm.	98.6 g cal/g
Azeotrope with water: boiling point, 760 mm, °C	94.3	MAC	25 ppm in air
methyl amyl alcohol, %w	55.6	Molecular weight	102.17
Boiling point at 760 mm	131.63 - 131.8°C	Non-volatile matter	0.005 g/100 ml max.
Coefficient of cubical expansion at 20°C/°C	0.00103	Odor	Mild and nonresidual
		Purity, minimum	97.5% by wt
Color, Pt-Co scale	10 max.	Refractive index at 20°C, n_D	1.4081 - 1.4113
Critical pressure, atm.	42.4	Solubility in water at 20°C	1.7 - 1.8% by wt
Critical temperature	312°C	Solubility of water in, at 20°C	5.8 - 6.2% by wt
Distillation range, 760 mm	130.0 - 133.0°C	Specific gravity at 20/20°C	0.8079 - 0.8080
Fire hazard	Moderate	Specific heat at 20°C	0.52 g cal/g-°C
Flash point, Tag open cup	131°F	Surface tension at 20°C	22.8 dynes/cm
Tag closed cup	106°F	Suspended matter	Substantially free
Freezing point	-90°C, sets to a glass below		

2-ETHYLBUTYL ALCOHOL

Table 6.99: Physical Properties of 2-Ethylbutyl Alcohol *(31)*

Acidity as acetic acid	0.02% max.	Solubility in water at 20°C	0.43% by wt
Boiling point at 760 mm	147.0°C	Solubility of water in, at 20°C	4.6% by wt
Boiling range at 760 mm below 140°C	None	Specific gravity at 20/20°C	0.8328
below 145°C	Not more than 5%	Specific heat at 25°C	0.586 cal/g
below 155°C	Not less than 95%	Surface tension at 28°C	28.05 dynes/cm
above 160°C	None	Vapor pressure at 20°C	1.2 mm
Coefficient of expansion per °C	0.000892 to 20°C 0.000921 to 55°C	Viscosity at 20°C	5.63 cps.
Dryness at 20°C	Miscible with 19 vol. of 60° Bé gasoline	Weight per gallon at 20°C	6.93 lbs
Flash point (ASTM open cup)	58°C (137°F)		
Heat of vaporization, 1 atm.	196 Btu/lb		
Molecular weight	102.17		
Non-volatile matter	0.005% max.		
Refractive index at 20°C	1.4229		

n-HEXYL ALCOHOL

n-Hexanol, Hexanol-1, Amyl Carbinol $CH_3(CH_2)_4CH_2OH$

Table 6.100: Physical Properties of n-Hexyl Alcohol *(31)*

Acidity as acetic acid	0.01% by wt
Boiling point at 760 mm	157.1°C
50 mm	89°C
10 mm	60°C
Boiling range at 760 mm	153 to 160°C
Color (Pt-Co Scale)	15 max.
Fire hazard	Moderate
Flash point (Open cup)	165°F
Freezing point	-44.6°C
Heat of vaporization at 1 atm.	213 Btu/lb
Hydroxyl number	530 min.
Iodine number	1.2 min.
Molecular weight	102.17
Odor	Mild
Refractive index at 20°C, n_D	1.4181
Solubility in water at 20°C	0.58% by wt
Solubility of water in, at 20°C	7.2% by wt
Specific gravity at 20/20°C	0.8203 - 0.8208
Specific heat at 16.9°C	0.544 Cal/gm/°C
at 13°C	0.500 Cal/gm/°C
Surface tension at 30°C	23.6 dynes/cm
Suspended matter	Substantially free
Vapor pressure at 20°C	0.43 mm
Viscosity (absolute) at 20°C	5.4 cps
Water content	Miscible without turbidity with 19 vol. of 60° API gasoline at 20°C
Weight per gallon at 20°C	6.83 lbs

Table 6.101: Solubility of Water in n-Hexyl Alcohol *(31)*

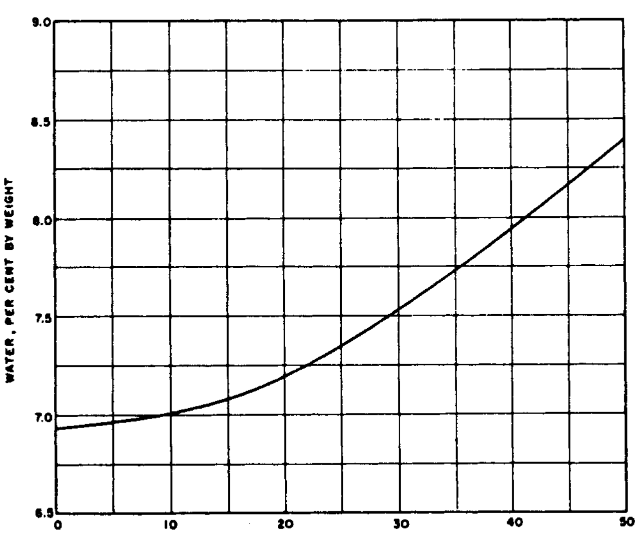


Table 6.102: Azeotropes of Hexyl Alcohol *(31)*

HEXYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
63.5	Anisole	151.0
27	Benzyl methyl ether	156.7
52	Camphene	150.8
56	o-Chlorotoluene	153.5
46	p-Chlorotoluene	154.0
65	Cumeme	149.5
53	2,7-Dimethyloctane	152.5
11	Isoamyl ether	157.0
40	Isoamyl propionate	156.7
60	Isobutyl butyrate	155.0
45	Mesitylene	153.5
19	Phenetole	157.7
60	α-Pinene	150.8
55	Propylbenzene	152.5
32	Pseudocumene	156.3
77	Styrene	144.0
85	m-Xylene	138.3
82	o-Xylene	143.6
87	p-Xylene	137.0

CYCLOHEXYL ALCOHOL

Table 6.103: Physical Properties of Cyclohexyl Alcohol *(31)*

Boiling point at 760 mm	161.1°C (322°F)
Boiling range at 760 mm, 5-95%	156-163°C
Color, APHA	10 max.
Crystallization point	-10°C min.
Dielectric constant at 25°C	15.0
Evaporation rate at 45°C (toluene = 100)	8 approx.
Fire hazard	Moderate
Flash point (Closed cup)	145°F
(Open cup)	154°F
Freezing point	18-25.15°C
Heat of combustion, liquid	8893 cal/g
Heat of fusion	4.9 cal/g
Heat of vaporization	108 cal/g
Ketone as cyclohexanone	0.5% max.
Phenol	0.05% max.
Refractive index at 20°C	1.4656
Solubility in water at 20°C	3.6% by wt.
Solubility of water in at 20°C	20% by wt.
Specific gravity at 20/4°C	0.9493
Specific heat at 15-18°C	0.417 cal/gm
Surface tension at 16.2°C	34.23 dynes/cm
Toxicity	Moderate by ingestion and inhalation
Vapor density (air = 1.00)	3.45
Vapor pressure at 20 °C	0.8 mm
70	15
80	27
100	78
120	187
140	398
150	554
161.1	760
Viscosity at 25 °C	49.8 centipoises
39.1°C	20.3 cps.
65.9°C	5.8 cps.
90 °C	2.45 cps.
Water	0.5% max.
Weight per gallon at 20°C (68°F)	7.91 lbs.

Table 6.104: Azeotropes of Cyclohexyl Alcohol *(31)*

CYCLOHEXYL ALCOHOL FORMS BINARY AZEOTROPES WITH

%		B. P. of Azeotrope °C
70	Anisole	152.5
38	Benzyl methyl ether	159.0
59	Camphene	151.9
85	Chloroacetal	155.6
62	o-Chlorotoluene	155.5
45	p-Chlorotoluene	156.5
8	Cineole	160.55
72	Cumene	150.0
28	Cymene	159.5
25	Indene	160.0
22	Isoamyl ether	158.8
37	Isoamyl propionate	157.7
80	Isobutyl butyrate	156.0
35	α-Phellandrene	158.0
60	Propylbenzene	153.8
83	Propyl isovalerate	155.1
40	Pseudocumene	158.0
35	α-Terpene	158.3
22	Thymene	159.8
95	m-Xylene	138.9
86	o-Xylene	143.0

HEPTYL ALCOHOL

Heptanol-1, Alcohol C-7 $C_7H_{15}OH$

Table 6.105: Physical Properties of Heptyl Alcohol *(31)*

Boiling point at 765 mm	175°C
Freezing point	-34.6°C
Refractive index at 20°C, n_D	1.4233
Specific gravity at 20/4°C	0.824

Table 6.106: Azeotropes of Heptyl Alcohol *(31)*

HEPTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
80	Benzyl methyl ether	167.0
90	Camphene	159.3
53	Cymene	172.5
50	Dipentene	171.7
63	Isoamyl ether	170.4
92	Isobutyl isovalerate	171.0
48	p-Methylanisole	173.0
72	Phenetole	169.0
60	α-Terpinene	169.7

2-HEPTYL ALCOHOL

Heptanol-2, Methylamyl Carbinol $CH_3(CH_2)_4CHOHCH_3$

2-Heptyl alcohol is a secondary alcohol.

Table 6.107: Physical Properties of 2-Heptyl Alcohol *(31)*

Acidity as acetic acid	0.03% by wt., max.
Boiling point at 760 mm	160.4°C
Boiling range at 760 mm, below 155°C	None
below 158°C	Not more than 5%
below 162°C	Not less than 95%
above 165°C	None
Color (Pt-Co scale)	15, max.
Dryness at 20°C	Miscible with 19 vols. 60° Bé gasoline
Fire hazard	Moderate
Flash point (Open cup)	160°F
Solubility in water at 20°C	0.35% by wt.
Solubility of water in at 20°C	5.80% by wt.
Specific gravity at 20/20°C	0.8187
Vapor pressure at 20°C	1.0 mm
Weight per gallon at 20°C	6.81 lbs.

3-HEPTYL ALCOHOL

Heptanol-3 $CH_3CH_2CH(OH)C_4H_9$

Table 6.108: Physical Properties of 3-Heptyl Alcohol *(31)*

Acidity as acetic acid	0.02% by wt.
Boiling point at 760 mm	156.2°C
Boiling range	153-158°C
Color, APHA (Pt-Co scale)	5
Fire hazard	Moderate
Flash point	140°F
Freezing point	-70°C sets to glass below
Specific gravity at 20/20°C	0.8224
Vapor pressure at 20°C	0.58 mm
Weight per gallon at 20°C	6.84 lbs.

2-ETHYLHEXYL ALCOHOL

2-Ethylhexanol, Octyl Alcohol $CH_2CH_2CH_2CH(C_2H_5)CH_2OH$

Table 6.109: Physical Properties of 2-Ethylhexyl Alcohol *(31)*

Acidity as acetic acid	0.01%, max.
Aldehydes	None
Boiling point at 760 mm	184.8°C
Boiling range, below 180°C above 192°C	None None
Coefficient of expansion per °C	0.000875 to 20°C 0.000902 to 55°C
Color, APHA	5 max.
Constant-boiling mixture, solvent 20% water 80%	b.p. 99.1°C
Fire hazard	Slight
Flash point, Open cup	185°F
Freezing point	-70°C sets to glass below
Heat of vaporization, 1 atm.	167 Btu/lb
Molecular weight	130.22
Refractive index at 20°C, n_D	1.4316
Solubility in water at 20°C	0.10% by wt
Solubility of water in, at 20°C	2.6% by wt
Specific gravity at 20/20°C	0.8339
Specific heat at 25°C	0.564 cal/gm/°C
Surface tension at 22°C	30.0 dynes/cm
Unsaturates, as ethyl hexanol	0.2% max.
Vapor pressure at 20°C	0.05 mm
Viscosity at 20°C	9.8 cps.
Weight per gallon at 20°C	6.94 lbs

n-OCTYL ALCOHOL

n-Octanol, Octanol-1 $CH_3(CH_2)_6CH_2OH$

Table 6.110: Physical Properties of n-Octyl Alcohol *(31)*

Acid number	0.2 max.
Boiling point at 760 mm	195°C (383°F)
Boiling range at 760 mm	194 - 197°C
Color, dichromate	0.002 max.
Ester number	1.3 max.
Fire hazard	Slight
Flash point (Open cup)	195°F
Freezing point	-15°C (5°F)
Heat of combustion	9690 cal/g
Hydroxyl number	415 - 440
Iodine number	1.3 max.
Molecular weight	130.22
Refractive index at 20°C, n_D	1.42920
Solubility in water at 25°C	0.059 g per 100 g water
Specific gravity at 20/4°C	0.827
Viscosity at 20°C	8.925 centipoise
Water	0.25% max.

Table 6.111: Azeotropes of n-Octyl Alcohol *(31)*

OCTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
80	N,N-Dimethyl-o-toluidine	184.8
88	Indene	182.4
85	Isoamyl isovalerate	192.6
70	Isobornyl methyl ether	191.9
80	Isobutyl carbonate	189.5
92	d-Limonene	177.5
20	Phorone	193.5
90	γ-Terpinene	182.5
93	Thymene	179.6

sec-OCTYL ALCOHOL

Table 6.112: Physical Properties of sec-Octyl Alcohol *(31)*

	85% Grade	95% Grade
Boiling range		
first 5%		173 - 178°C
90%	174 - 181.5°C	178 - 182.5°C
Density, lbs per gallon	6.8	6.8
Fire hazard	Moderate	Slight
Flash point	164°F	185°F
Hydroxyl number	376 - 388	408 - 414
Melting point		-38°C
Methyl hexyl ketone content	10 - 15%	Less than 5%
Molecular weight	130.23	130.23
Refractive index at 20°C	1.4244 - 1.4252	1.4258 - 1.4262
Specific gravity at 20°C	0.814 - 0.820	0.818 at 25°C
Water content	1.0 - 1.2%	0.3 - 0.5%

Table 6.113: Azeotropes of sec-Octyl Alcohol *(31)*

sec-OCTYL ALCOHOL FORMS BINARY AZEOTROPES WITH:

%		B.P. of Azeotrope °C
14	Amyl ether	179.8
50	Butylbenzene	178.2
89	Butyl isovalerate	177.4
73.5	Cineole	175.9
56	Cymene	174.0
40	Indene	176.0
28	Isoamyl butyrate	180.3
83	Isoamyl ether	172.7
55	d-Limonene	174.5
73	α-Terpinene	171.8
43	Terpinolene	179.0
48	Thymene	176.0

ISOOCTYL ALCOHOL

Table 6.114: Physical Properties of Isooctyl Alcohol *(31)*

Acidity as acetic acid	0.001% by wt
Carbonyl number	0.10 mg KOH/g
Coefficient of expansion per °C	0.000814
Color (Hazen, Pt-Co)	5
Fire hazard	Slight
Flash point (Tag open cup)	180°F
Pour point	-95°F
Purity	99.5% by wt
Refractive index at 20°C, n_D	1.4308
Solubility in water at 25°C	0.06 g/100g
at 50°C	0.08 g/100g
Solubility of water in, at 5°C	3.4 g/100g
20°C	3.8 g/100g
40°C	4.1 g/100g
Specific gravity at 20/20°C	0.832
60/60°F	0.834
Specific heat, 50 - 150°C	0.79 cal/g/°C
Surface tension at 20°C	29.5 dynes/cm
Vapor pressure, °C °F	mm
50 122	1.95
75 167	8.4
100 212	30
125 257	94
150 302	250
175 347	600
180 356	700
Viscosity, °C °F	Centistokes
37.8 100	6.4
20.0 68	12.7
-9.4 15	51.3
-17.8 0	84.4
-31.7 -25	224.2
Water	0.02% by wt
Weight per gallon at 60°F	6.95 lbs, approx.

NONYL ALCOHOL

Table 6.115: Physical Properties of Nonyl Alcohol *(31)*

Aldehyde content	0.30% by wt
Boiling point at 760 mm	173.3°C
Color, Saybolt	30
Distillation (ASTM), initial	193°C
5%	196°C
50%	198°C
95%	201°C
max.	206°C
Fire hazard	Moderate
Flash point (Open cup)	80°C (176°F)
Freezing point	-65°C
Heat of vaporization (Lv),	
100°F	22,000 Btu/lb mole
300°F	19,000 Btu/lb mole
400°F	17,400 Btu/lb mole
Mixed aniline point	-15°C
Neutralization number	0.02 mg KOH/g
Refractive index at 20°C, n_D	1.4390
Solubility in water at 20°C	0.06% by wt
Solubility of water in, at 20°C	0.99% by wt
Specific gravity at 20/20°C	0.8121
Vapor pressure at 20°C	0.3 mm
Viscosity at 0°C	56.0 cps.
at 20°C	14.3 cps.
Weight per gallon at 20°C	6.75 lbs

3,5,5-TRIMETHYLHEXYL ALCOHOL

Table 6.116: Physical Properties of 3,5,5-Trimethylhexyl Alcohol *(31)*

Boiling point at 10 mm	83°C (181°F)
760 mm	194°C (381°F)
Boiling range at 760 mm,	
first drop	190°C
90%	194 ± 1°C
dry	195.5°C
Color (APHA)	25 max.
Flash point (Open cup)	200°F
Freezing point	Below -70°C
Molecular weight	144.25
Purity (by hydroxyl number)	97.5% min.
Refractive index at 25°C, n_D	1.4300
Specific gravity at 25/4°C	0.8236
Viscosity at 25°C	11.06 centipoises
Water content	0.15% max.
Weight per gallon at 25°C	6.86 lbs

DECYL ALCOHOL

Table 6.117: Physical Properties of Decyl Alcohol *(31)*

	Oxo Process	Fatty acid Process
Acidity	0.0015% by wt.	
Acid number		0.2 max.
Aldehydes, as decanal	0.20%, max.	
Boiling point at 760 mm	217.3°C	231°C (448°F)
Boiling range at 760 mm	219-221.5°C	90% between 229-233°C
Coefficient of expansion at 55°C	0.00086	
Color, Hazen Pt-Co	5	0.003 max., Dichromate
Ester, as decyl formate	Less than 0.1%	
Ester number		1.3 max.
Fire hazard	Slight	Slight
Flash point (Open cup)	225°F	220°F
Freezing point	Sets to a glass below -60°C	6.9°C (44°F)
Heat of combustion		9963 cal/g
Hydroxyl number		345-365
Iodine number		0.5 max.
Molecular weight	158.28	158.28
Pour point	-95°F	
Purity	99.7%-99.9% by wt.	
Refractive index at 20°C, n_D	1.4388-1.4390	1.43682

			Oxo Process	Fatty Acid Process
Solubility in water at 20°C			Less than 0.01% by wt.	
Solubility of water in at 20°C			2.3% by wt.	
Specific gravity at 20/20°C			0.837-0.840	0.829 at 20/4°C
Sulfur			4 ppm, max.	
Suspended matter			Substantially free	
Vapor pressure,	°C	°F	mm	
	75	167	2.1	
	100	212	8.4	
	125	257	28.2	
	150	302	82	
	175	347	225	
	200	392	500	
Viscosity,	°C	°F	Centistokes	
	99	210	1.76	
	20	68	21	13.83 centipoises
	- 9.4	15	115	
	-17.8	0	209	
	-31.7	-25	701	
	-40.0	-40	1649	
	-53.9	-65	8826	
Water content			0.03-0.07% by wt.	0.25%
Weight per gallon at 20°C			7.03 lbs.	
60°F			6.96 lbs. approx.	

ISODECYL ALCOHOL

Table 6.118: Physical Properties of Isodecyl Alcohol *(31)*

Acidity as acetic acid	0.002% by wt., max.
Aldehydes, as decanal	0.05% by wt., max.
Boiling point at 760 mm	220.1°C
Boiling range at 760 mm, Ibp	215°C, min.
Dp	225°C, max.
Coefficient of expansion at 55°C	0.00083
Color, (Pt-Co scale)	10, max.
Fire hazard	Slight
Flash point (Open cup)	220°F
Freezing point	Sets to a glass below -60°C
Molecular weight	158.29
Odor	Characteristic, non-petroleum
Purity, as decanol	98.5% by wt., min.
Refractive index at 20°C, n_D	1.4408
Solubility in water at 20°C	Less than 0.01% by wt.
Solubility of water in at 20°C	2.4% by wt.
Specific gravity at 20/20	0.8423
Sulfuric acid test (Pt-Co scale)	50, max.
Suspended matter	Substantially free
Vapor pressure at 20°C	Less than 0.01 mm
Viscosity at 20°C	18.9 cps.
Water content	0.10% by wt., max.
Weight per gallon at 20°C	7.01 lbs.

TRIDECYL ALCOHOL

Table 6.119: Physical Properties of Tridecyl Alcohol *(31)*

Acidity as acetic acid			0.002% by wt
Carbonyl number			0.7 mg KOH/g
Color, Hazen, Pt-Co			5
Distillation: initial			252°C
dry point			269°C
Fire hazard			Slight
Flash point (Tag open cup)			180°F
Hydroxyl number			278 mg KOH/g
Odor			Characteristic, non-petroleum
Pour point			-95°F
Purity			99.6% by wt
Refractive index at 20°C, n_D			1.4475
Specific gravity at 20°C			0.8454
Sulfur			2 ppm
Vapor pressure,	°C	°F	mm
	90	194	1.3
	100	212	2.2
	125	257	7.8
	150	311	24
	175	347	64
	200	401	155
	225	437	340
	250	491	685
Viscosity,	°C	°F	Centipoises
	99	210	2.61
	20	68	47.5
	- 9.4	15	382.2
	-17.8	0	808.3
	-31.7	-25	3,692
	-40.0	-40	11,081
	-53.9	-65	95,433
Water			0.10% by wt.
Weight per gallon at 60°F			7.0 lbs.

OTHER ALCOHOLS AND ALCOHOL BLENDS

Table 6.120: ALFOL Alcohol Low Range Blends C_6—C_{10} *(40)*

Typical Properties	610	610 AFC	610 ADE	810	810 AI	810 EE
Total alcohol, Wt. %	99.8	99.8	99.6	99.8	99.7	99.6
Molecular weight distribution (100% alcohol basis)						
C4						
C6	4.8	4.8	9.0	0.6	0.1	0.6
C8	43.2	54.4	42.7	45.7	10.5	49.4
C10	51.3	40.1	47.8	53.2	89.1	49.5
C12	0.7	0.7	0.5	0.5	0.3	0.5
C14	trace	–	–	–	trace	–
Average alcohol MW	140	135	138	145	153	141
Color, APHA	0	0	0	0	0	0
Water, Wt. %	0.03	0.03	0.02	0.02	0.02	0.03
Iodine number	0.05	0.05	0.05	0.02	0.02	0.02
Hydroxyl number	401	415	407	387	367	397
Carbonyl, as ppm C=0	30	30	30	30	30	30
Acidity, as acetic acid, %	0.002	0.002	0.002	0.003	0.003	0.003
Acid Heat Color, APHA	10	–	10	–	–	–
Specific gravity	0.824	0.830	0.829	0.831	0.831	0.831
at ° F/° F	77/77	60/60	60/60	60/60	60/60	60/60
Flash point, (PM) ° F	175	175	167	188	203	200
Melting range, ° F	1–5	1–5	1–5	3–7	3–7	3–7
Boiling range, ° F	351–459	350–460	350–460	401–459	400–460	400–460
Saponification number	0.19	0.27	0.19	0.4	–	–
Viscosity, cSt 70° F	11	11	11	13.4	16.3	13.5
100° F	6.4	6.6	7.7	7.4	8.7	7.2
Coefficient of thermal expansion lb/gal/° F	0.00334	0.00334	0.00334	0.00325	0.00334	0.00317

Table 6.121: ALFOL Alcohol Pure Homologs C_6—C_{18} *(40)*

Typical Properties	6	8	10
Total alcohol, Wt.%	99.4	99.9	99.8
Molecular weight distribution (100% alcohol basis)			
C6	99.4	trace	–
C8	0.6	99.9	0.5
C10	trace	0.1	99.3
C12	trace	–	0.2
C14	–	–	–
C16	–	–	–
C18	–	–	–
C20	–	–	–
Average Molecular Weight	102	130	158
Color, APHA	0	0	0
Water, Wt.%	0.04	0.03	0.02
Iodine number	0.05	0.03	0.05
Hydroxyl number	545	430	351
Carbonyl, as ppm C=O	28	12	7
Acidity, as acetic acid, %	0.001	0.001	0.001
Specific gravity,	0.8232	0.8293	0.8335
at ° F/° F	60/60	60/60	60/60
Flash point, (PM) ° F	130	180	235
Melting range, ° F	–49	1–3	43–45
Boiling range, ° F	313–316	381–385	448–453
Saponification number	<0.04	<0.04	<0.04
Viscosity, cSt 70° F	5.5	10.5	14.5
100° F	3.5	6	9
Coefficient of thermal expansion lb/gal/F	0.00376	0.00351	0.00334

(continued)

Table 6.121: (continued)

Typical Properties	12	14	16	16NF	18	18NF
Total alcohol, Wt.%	99.8	99.8	99.8	99.8	99.6	99.6
Molecular weight distribution						
(100% alcohol basis)						
C6	–	–	–	–	–	–
C8	–	–	–	–	–	–
C10	0.1	trace	–	–	–	–
C12	99.6	0.4	trace	trace	–	–
C14	0.3	99.4	0.3	0.3	0.1	0.1
C16	–	0.3	98.7	98.7	0.3	0.3
C18	–	–	0.7	0.7	98.4	98.4
C20	–	–	–	–	0.9	0.9
Average Molecular Weight	187	214	242	242	271	271
Color, APHA	5	5	5	5	5	5
Water, Wt.%	0.01	0.02	0.02	0.02	0.02	0.02
Iodine number	0.05	0.03	0.18	0.18	0.33	0.33
Hydroxyl number	299	258	227	227	207	207
Carbonyl, as ppm C=O	8	29	64	64	241	241
Acidity, as acetic acid, %	0.005	0.003	0.011	0.011	0.008	0.008
Specific gravity,	0.83	0.815	0.813	0.813	0.811	0.811
at ° F/° F	60/60	120/120	125/125	125/125	140/140	140/140
Flash point, (PM) ° F	265	290	300	300	355	355
Melting range, ° F	73–76	98–102	118–121	113–122	132–136	131–140
Boiling range, ° F	490–498	567–573	626–631	626–631	662–670	662–670
Saponification number	0.04	0.07	0.06	0.06	0.1	0.1
Viscosity, cSt 70° F	80F/19	–	–	–	–	–
100° F	12.3	15	120F/18	120F/18	160F/13.5	160F/13.5
Coefficient of thermal						
expansion lb/gal/F	0.00325	0.00317	0.00317	0.00317	0.00309	0.00309

Table 6.122: ALFOL Alcohol High Range Blends C_{10}—C_{20+} *(40)*

Typical Properties	1012 HA	1014 CDC	1214	1214 GC	1216	1216 CO
Total Alcohol, Wt. %	99.8	99	99.5	99	99	99.7
Homolog Distribution, Wt. %						
C8	0.6	–	0.1	trace	–	0.1
C10	87.5	31	0.6	0.8	0.3	0.4
C12	6.8	36.6	56.5	68.2	64.3	67.2
C14	5	31.2	42.2	30.3	24	25.3
C16	0.1	–	0.6	0.7	11.4	6.8
C18	–	–	–	–	trace	0.2
C20	–	–	–	–	–	–
C22	–	–	–	–	–	–
C24	–	–	–	–	–	–
C26	–	–	–	–	–	–
C28	–	–	–	–	–	–
C30	–	–	–	–	–	–
Avg. Molecular Weight	164	186	198	195	203	198
Color, APHA	0	0	0	0	5	5
Water, Wt. %	0.02	0.05	0.08	0.06	0.05	0.04
Iodine number	0.04	0.07	0.05	0.05	0.1	0.08
Hydroxyl number	343	302	284	287	276	284
Carbonyl, ppm C=0	31	123	45	21	40	47
Specific Gravity	0.834	0.836	0.838	0.838	0.84	0.84
° F/° F	72/72	72/72	72/72	72/72	72/72	72/72
Flash Point (PM) ° F	237	250	265	265	265	265
Melting Range, ° F	35–40	41–45	70–75	70–75	63–70	63–70
Boiling Range, ° F	425–525	450–545	518–575	518–575	514–592	529–590
Viscosity, cSt	10.4	12.5	14.3	14.3	14.5	14.5
Temperature, ° F	100	100	100	100	100	100
Coefficient of Thermal						
Expansion, lb/gal/F	0.00321	0.003	0.00316	0.00316	0.00316	0.00316
Saponification number	0.1	0.1	0.1	0.18	0.5	0.18
Appearance	clear colorless liquid	clear colorless liquid	clear colorless liquid	clear colorless liquid	clear colorless liquid	clear colorless liquid

(continued)

Table 6.122: (continued)

Typical Properties	1218 DCBA	1412	1416 GC	1418 DDB	1418 GBA	1618	1618 CG	1618 GC	20+
Total Alcohol, Wt. %	99.6	99.7	99.8	99.9	99.8	99.6	99.6	98.5	88.5
Homolog Distribution, Wt. %									
C8	trace	trace	–	–	–	–	–	–	–
C10	0.5	0.5	0.1	–	trace	–	–	–	–
C12	38.3	37.7	6.3	0.7	0.6	trace	trace	–	–
C14	30	60.6	63.4	39.5	66.4	1.3	0.6	0.6	–
C16	19.8	1.2	29.8	38.7	25.6	61	31.9	66.2	trace
C18	10.8	–	0.4	19.6	7	35.7	66.1	31.4	1.2
C20	0.6	–	–	1.5/>C20	0.4	2	1.4	1.6/>C20	54.3
C22	–	–	–	–	–	–	–	–	25.8
C24	–	–	–	–	–	–	–	–	11.1
C26	–	–	–	–	–	–	–	–	4.6
C28	–	–	–	–	–	–	–	–	2.1
C30	–	–	–	–	–	–	–	–	1
Avg. Molecular Weight	214	205	222	243	227	256	266	263	431
Color, APHA	5	5	10	10	5	5	5	5	848
Water, Wt. %	0.06	0.06	0.03	0.03	0.05	0.04	0.03	0.04	0.03
Iodine number	0.11	0.1	<0.4	0.6	<0.7	0.15	0.15	0.8	8.7
Hydroxyl number	262	274	253	231	247	219	211	213	157
Carbonyl, ppm C=0	48	48	110	–	77	180	155	150	1930
Specific Gravity	0.84	0.839	0.822	0.819	0.835	0.840	0.820	0.820	0.817
° F/° F	72/72	72/72	100/100	110/110	100/100	60/60	120/120	140/140	140/140
Flash Point (PM) ° F	275	270	305	290	305	325	340	325	390
Melting Range, ° F	68–73	72–75	95–99	97–102	97–102	110–120	110–120	110–120	113–129
Boiling Range, ° F	525–660	525–585	582–638	598–659	598–660	628–662	630–670	630–670	>650
Viscosity, cSt	15.0	14.4	11.5	14.6	–	15.0	13.7	–	5.3
Temperature, ° F	100	100	100	110	–	122	140	–	210
Coefficient of Thermal Expansion, lb/gal/F	0.00313	0.00314	0.0028	0.0028	0.0028	0.00303	0.00310	0.003	0.00313
Saponification number	0.18	<1	<1	0.5	<1.0	0.07	0.07	0.5	5.7
Appearance	clear colorless liquid	white solid	white solid	white solid	white solid	white solid	white solid	white solid	off-white solid

Table 6.123: ALFOL Typical Properties *(40)*

Typical Properties	ALFOL® 6	ALFOL® 8	ALFOL® 10	ALFOL® 610	ALFOL® 810	ISOFOL® 12
Total Alcohol, wt %	99.4	99.9	99.8	99.6	99.8	min. 95
Molecular Weight Distribution (100% alcohol basis)						
C4						
C6	99.4	trace	-	9	0.6	
C8	0.6	99.9	0.5	42.7	45.7	
C10	trace	0.1	99.3	47.8	53.2	
C12	trace	-	0.2	0.5	0.5	
2-Butyloctanol						min. 95
Average Molecule weight	102	130	158	138	145	186 approx.
Color, ALPHA	0	0	0	0	0	20 max
Water, wt%	0.04	0.03	0.02	0.02	0.02	0.1 max
Iodine Number	0.05	0.03	0.05	0.05	0.02	1.0 max
Hydroxyl Number	545	430	351	407	387	286-305
Carbonyl, as C=O ppm	28	12	7	30	30	150
Specific gravity at F/°F	0.8232 60/60	0.8293 60/60	0.8335 60/60	0.829 60/60	0.831 60/60	
Flash point, (PM)° F	130	180	235	167	188	248 (ISO 2592)
Melting Range, °F	-49	3-Jan	43-45	1-5	3-7	<22
Boiling Range, °F	313-316	381-385	448-453	350-460	401-460	291-300
Saponification Number	<0.04	<0.04	<0.04	0.19	0.4	1.0 max.
Viscosity, cSt at 70° F	5.5	10.5	14.5	11	13.4	
at 100°F	3.5	6	9	7.7	7.4	
Coefficient of thermal expansion lb/gal/°F	0.00376	0.00351	0.00334	0.00334	0.00325	

COMPARATIVE DATA

Table 6.124: Ashland Alcohols *(69)*

PRODUCT	LB./GAL. 20°C	SP. GR. 20°/20° C	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F TCC	EVAP. RATE[1]
Methanol	6.60	0.791	64-65	147-149	54	2.1
Ethanol, Anhydrous	6.58	0.790	74-80	165-176	53	1.7
Ethanol, 95%	6.76	0.811	75-80	167-176	55	1.7
Isopropanol 91%	6.81	0.816	80-81	176-178	63	1.3
Isopropanol, Anhydrous	6.55	0.786	82-83	180-182	53	1.6
n-Propanol	6.71	0.806	96-98	205-208	74	1.3
2-Butanol	6.72	0.808	98-101	208-214	72	1.2
Isobutanol	6.68	0.803	107-109	225-228	86	0.6
n-Butanol	6.75	0.811	116-119	241-246	97	0.42
Amyl Alcohol (primary)	6.79	0.815	127-139	261-282	113	0.27
Methyl Amyl Alcohol	6.72	0.808	130-133	266-271	103	0.27
Cyclohexanol	7.91	0.946[4]	160-163	320-325	140[3]	0.05
2-Ethylhexanol	6.94	0.834	182-186	360-367	164	< 0.01

[1] n-Butyl Acetate = 1 [3] COC [4] At 30°C

Table 6.125: Chemcentral Alcohols *(67)*

ALCOHOLS	CAS	Mole Weight	% Purity Comm. Prod.	Spec. Grav. @ 20/20°C	Lbs./Gal. @ 20°C	Coeff. of Expan. Per °C	Δ Sp. Gr. Per °C	Refractive Index @ 20°C	Distillation Range @ 760 mm Hg °C	Distillation Range @ 760 mm Hg °F
AMYL ALCOHOL (Mixed Isomers)		88.15	99.6	0.813	6.79	0.00093	00056	1.409	127-137	261-279
iso BUTYL ALCOHOL	78-83-1	74.13	99	0.803	6.69	0.00099	00060	1.396	106-109	223-229
n BUTYL ALCOHOL	71-36-3	74.12	99.8	0.811	6.75	0.00093	00056	1.3992	117-118	243-245
sec BUTYL ALCOHOL	78-92-2	74.12	99.7	0.808	6.73	0.00091	00054	1.3971	98-101	208-214
CYCLOHEXANOL	**108-93-1**	**100.16**	**99**	**0.946**	**7.91**	**0.00077**	**.00050**	**1.4626**	**160-161.2**	**320-322**
ETHANOL, ANHYDROUS PROPRIETARY	64-17-5	46.07	99	0.792	6.62	0.00120	00076	1.3638	74-80	165-176
ETHANOL, 95% PROPRIETARY	64-17-5	46.07	95	0.812	6.74	0.00118	00076		74-80	165-176
FURFURAL ALCOHOL	98-00-0	98.1	98.0	1.135	9.44			1.4868	170-BP	338-BP
METHYL ALCOHOL (Methanol)	67-56-1	32.04	99.98	0.793	6.60	0.00120	.00080	1.3284	64-65	147-149
METHYL AMYL ALCOHOL (MIBC)	**108-11-2**	**102.17**	**98**	**0.808**	**6.73**	**0.00103**	**.00064**	**1.4113**	**130-133**	**266-271**
iso PROPYL ALCOHOL, ANHYDROUS	67-63-0	60.09	99.9	0.787	6.57	0.00111	00068	1.3766	82-83	180-181
iso PROPYL ALCOHOL, 91%	67-63-0	60.09	91.3	0.818	6.84	0.00111	.00072		79.7-80.7	175-177
n PROPYL ALCOHOL	71-23-8	60.09	99.8	0.805	6.70	0.00095	00058	1.3854	96-98	204-208
TETRAHYDROFURFURAL ALCOHOL		102.13	98.0	1.054	6.79	0.00074	.00075	1.4520	178-BP	353-BP
TEXANOL*	**25265-77-4**	**216.3**		**0.950**	**7.90**				**244-247**	
TRIDECYL ALCOHOL	112-70-9		99.0	0.845	7.04				252-263	465-506

ALCOHOLS	Vapor Press. @ 20°C mm Hg	Evap. Rate vs. B. Acet. = 1	Visc. cps @ 20°C	Solubility % by Wt. @ 20°C In H_2O	Solubility % by Wt. @ 20°C Of H_2O	Dilution Ratio Tol. Lac.	Freeze Point °C	Flash Point T.C.C. °F	Explosive Limits % by Vol. in Air Lower	Explosive Limits % by Vol. in Air Upper	Solubility Parameter
AMYL ALCOHOL (Mixed Isomers)	2.0	0.3	4.6	1.7	9.2	Latent	−90	110	1.2	10.0[3]	11.1
iso BUTYL ALCOHOL	8.8	0.63	3.9	9.5	16.9	Latent	−108	85	1.45	11.25	11.6
n BUTYL ALCOHOL	4.39	0.46	2.95	7.9	20.1	Latent	−89.8	97	1.2[C]	10.9[3]	11.2
sec BUTYL ALCOHOL	12.7	0.9	3.65	22.5	60.0	Latent	−114.7	74	1.7	9.8[3]	11.1
CYCLOHEXANOL	**1.0**	**0.08**		**4.2**	**11.2**	**Latent**	**25.3**	**138**			**11.4**
ETHANOL, ANHYDROUS PROPRIETARY	44.0	1.9	1.19	∞	∞	Latent	−114.4	54	3.3	19.0	12.8
ETHANOL, 95% PROPRIETARY		1.7		∞	∞	Latent		58	3.3	19.0	12.8
FURFURAL ALCOHOL	1		4.5	∞	∞			167[2]	1.8	16.3	12.5
METHYL ALCOHOL (Methanol)	96.0	3.5	2.0	∞	∞	2.2:0.5	−97	54	6.7	36.0	14.5
METHYL AMYL ALCOHOL (MIBC)	**2.2**	**0.3**		**1.64**	**6.35**	**Latent**	**−90**	**106**	**1.0**	**5.5**	**10.0**
iso PROPYL ALCOHOL, ANHYDROUS	31.2	1.7		∞	∞	Latent	−89.5	53	2.0	12.0	11.4
iso PROPYL ALCOHOL, 91%		1.6		∞	∞	Latent		61	2.0	12.0	10.0
n PROPYL ALCOHOL	14.5	0.89		∞	∞	Latent	−127	71	1.5	13.5	11.9
TETRAHYDROFURFURAL ALCOHOL	2.0	0.07		∞	∞		−80	163[2]	2.6	9.7	10.8
TEXANOL*		**< 0.01**	**6.2**	**0.0**	**0.9**			**248[2]**			**8.2**
TRIDECYL ALCOHOL								259			

*Trade Mark Eastman Chemical Products Inc. @ 15.6°C [2] Open Cup [3] @ 100°C

Table 6.126: CPS Chemical Alcohol 99% *(15)*

TYPICAL PROPERTIES

TRADE NAME	CHEMICAL NAME	CAS NUMBER	PURITY WT. %	COLOR APHA	MOISTURE KF, WT. %	MOLECULAR WEIGHT	SPECIFIC GRAVITY 20/20 °C
ALCOHOLS							
Isoamyl Alcohol 99% (Natural)	Same	123-51-3	99.0	20	0.2	88	0.811
Isoamyl Alcohol 95% (Natural)	Same	123-51-3	95.0	50	0.5	88	0.811

Kosher available upon request

CPS SALES SPECIFICATIONS

ISOAMYL ALCOHOL 95%

TEST		SPECIFICATION
1071	PURITY, WT%, GC	95.0 min.
1013	MOISTURE, KF, WT%	0.50 max.
1011	COLOR, APHA	50 max.
1082	ACIDITY AS ACETIC ACID, WT%	0.01 max.
1097	SPECIFIC GRAVITY @20/20C	0.810 - 0.813
1096-B	DISTILLATION RANGE, IBP, C	126.0 - 500
1096-A	DISTILLATION RANGE, DP, C	132.0 max.
1017	APPEARANCE-CLEAR LIQUID/FFSM	

Table 6.127: Eastman Latent Solvents *(41)*

LATENT SOLVENTS	Evaporation Rate nBuOAc = 1	Evaporation Rate Ether = 1	Formula	Viscosity, cP 8% RS ½-s NC @25°C	Viscosity, cP 8% CAB-381-0.5 @ 25°C	Neat Viscosity cP	Neat Viscosity °C	Dilution Ratio[b] Toluene	Dilution Ratio[b] VM&P Naphtha	Blush Resistance % RH @ 80°F	Specific Gravity @ 20°/20°C	Weight/Volume @ 20°C Lb/Gal	Weight/Volume @ 20°C Kg/L	Flash Point TCC, °F	Freezing Point, °F
METHYL ALCOHOL	3.5	3.5	CH_3OH	20		0.60	20	2.2	0.5		0.792	6.60	0.79	50	—
TECSOL INDUS. AND PROPRIETARY SOLVENTS[o]	**1.7–1.9**	**—**	**C_2H_5OH**			**1.2–1.5**	**20**				**0.789–0.820**	**6.57–6.83**	**0.79–0.82**	**50**	**−173**
ISOPROPYL ALCOHOL, 99%	[illegible]	7.1	$(CH_3)_2CHOH$			2.40	20				0.786	6.54	0.78	55	127
n-PROPYL ALCOHOL	1.0	12.1	C_3H_7OH			2.00	25				0.804	6.71	0.80	74	−197
SECONDARY BUTYL ALCOHOL	0.9	13.4	$CH_3CH_2CHOHCH_3$			2.90	25				0.810	6.73	0.81	72	—
ISOBUTYL ALCOHOL	**0.6**	**20.2**	**$CH_3CH(CH_3)CH_2OH$**			**4.00**	**20**				**0.803**	**6.68**	**0.80**	**85**	**−162**
n-BUTYL ALCOHOL	0.5	24.2	C_4H_9OH			3.00	20				0.811	6.75	0.81	97	−129
METHYL ISOBUTYL CARBINOL	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]				0.805[h]	6.69[i]	[illegible]	[illegible]	[illegible]
AMYL ALCOHOL (MIXED PRIMARY ISOMERS)	0.3	40.3	$C_5H_{11}OH$			4.30	20				0.814[h]	6.77[i]	0.81[i]	—	−130
CYCLOHEXANOL	0.05	242.0	$CH_2(CH_2)_4CHOH$			52.70	25				0.947[h]	7.87[i]	0.94[i]	—	—
2-ETHYLHEXANOL	0.01	1,210.2	$C_4H_9CH(C_2H_5)CH_2OH$			7.70	25				0.833	6.94	0.83	164	−94

LATENT SOLVENTS	Vapor Pressure Torr	Vapor Pressure °C	Vapor Pressure KPa @ 55°C[c]	Surface Tension Dyne/Cm	Surface Tension °C	Boiling Range @ 760 Torr, °C	Solubility @ 20°C Wt % In Water	Solubility @ 20°C Wt % Water In	Azeotrope BP, °C	Azeotrope Wt % Water[d]	Autoignition Temperature, °C	Refractive Index Value	Refractive Index °C	Electrical Resistance,[e] Megohms	Hansen Solubility Parameters[f] Total	Nonpolar	Polar	Hydrogen Bonding	Gram Molecular Weight	TLV PPM 1992
METHYL ALCOHOL	100.0	21.2	69.0	22.6	20	64–65	Complete	Complete	None	—	463	1.3286	20	<0.1	14.5	7.4	6.0	10.9	32.04	200
TECSOL INDUS. AND PROPRIETARY SOLVENTS[o]	**—**	**—**	**37.6[p]**	**22.4**	**20**	**74–82**	**Complete[q]**	**Complete[q]**	**78.1**	**4.0**	**419**	**1.3614**	**20**	**<0.1**	**13.0**	**7.7**	**4.3**	**9.5**	**46.07**	**—**
ISOPROPYL ALCOHOL, 99%	32.8	20	30.6	21.3	20	80.8–83.5	Complete	Complete	80.3	12.6	360	1.3776	20	[illegible]	[illegible]	7.7	3.0	8.0	60.10	400
n-PROPYL ALCOHOL	14.5	20	15.7	23.8	20	96–98	Complete	Complete	87.0	28.3	413	1.3856	20	[illegible]	12.0	7.8	3.3	8.5	60.10	200
SECONDARY BUTYL ALCOHOL	12.0	20	—	24.0	20	98–101	20.6	30.7	87.0	26.8	406	1.3972	20	<0.2	10.8	7.7	2.8	7.1	74.12	100
ISOBUTYL ALCOHOL	**9.0**	**20**	**9.5**	**22.8**	**20**	**106–109**	**9.5**	**14.3**	**89.8**	**33.0**	**416**	**1.3955**	**20**	**<0.2**	**11.1**	**7.4**	**2.8**	**7.8**	**74.12**	**50**
n-BUTYL ALCOHOL	5.5	20	[illegible]	24.6	20	116–119	[illegible]	[illegible]	[illegible]	42.5	355	1.3993	20	[illegible]	11.3	7.8	2.8	7.7	74.12	50
METHYL ISOBUTYL CARBINOL				[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
AMYL ALCOHOL (MIXED PRIMARY ISOMERS)	2.9	20	—	23.8	20	127–13[illegible]	1.7	9.2	95.8	54.4	—	1.4014	20	0.2	—	—	—	—	88.15	
CYCLOHEXANOL	0.9	20	—	35.1	20	160–162	0.1	11.8	97.8	80.0	300	1.4656	20	0.4	11.0	8.5	2.0	6.6	100.16	50
2-ETHYLHEXANOL	0.05	20	0.26	28.7	20	182–18[illegible]	0.1	[illegible]	99.1	80.0	288	1.4316	20	>20	9.9	7.8	1.6	5.8	130.20	

Denatured Alcohols Marketed by Eastman *(41)*

Composition	*Tecsol* Special Industrial Solvents[a] A	A-2	B	C	D	D-2	H	*Tecsol* Proprietary Solvents[a] 1	3	Completely Denatured Alcohol[a] CDA-19
SDA-3A	100	100	100	100	100	100	100	—	—	—
SDA-1	—	—	—	—	—	—	—	100	100	—
Ethyl alcohol	—	—	—	—	—	—	—	—	—	100
MIBK	1	1	1	1	1	1	—	—	1	4
Isopropyl alcohol	10	—	5		15	—	100	—	—	—
Methyl alcohol	—	10	5		—	15	—	—	—	—
Ethyl acetate	—	—	—	5	—	—	—	5	1	
Heptane	—	—	—		—	—	—	1	1	1

Base for special industrial alcohol and proprietary alcohol:

SDA-3A—100 gallons ethyl alcohol with 5 gallons synthetic methanol

SDA-1—100 gallons ethyl alcohol with 4 gallons synthetic methanol and 1 gallon MIBK

[a]*Available as 95% (190 proof) or anhydrous (200 proof); in gallons*

(continued)

Table 6.127: (continued)

Denatured Alcohol Nomenclature *(41)*

Eastman	Union Carbide	Quantum	Grain Processing
Tecsol 1, 95% *Tecsol* 1, Anhydrous	*Synasol* PM 41 *Synasol* PM 100	*Solox*-1 *Solox*-1, Anhydrous	GPC 190 Gov't Form I (1-1) Anhydrous GPC Gov't Form I (1-1)
Tecsol 3, 95% *Tecsol* 3, Anhydrous	*Synasol* PM 3224 *Synasol* PM 509	*Solox* *Solox*, Anhydrous	GPC 190 Gov't Form III (1-1) Anhydrous GPC Gov't Form III (1-1)
Tecsol A, 95% *Tecsol* A, Anhydrous	*Anhydrol* PM 4081 *Anhydrol* PM 4082	*Filmex* A-1 *Filmex* A-1, Anhydrous	GPC 190 Gov't Form A (3A) Anhydrous GPC Gov't Form A (3A)
Tecsol A-2, 95% *Tecsol* A-2, Anhydrous	*Anhydrol* PM 4079 *Anhydrol* PM 4083	*Filmex* A-2 *Filmex* A-2, Anhydrous	GPC 190 Gov't Form A2 (3A) Anhydrous GPC Gov't Form A2 (3A)
Tecsol B, 95% *Tecsol* B, Anhydrous	*Anhydrol* PM 4157 *Anhydrol* PM 4135	*Filmex* B *Filmex* B, Anhydrous	GPC 190 Gov't Form B (3A) Anhydrous GPC Gov't Form B (3A)
Tecsol C, 95% *Tecsol* C, Anhydrous	*Anhydrol* PM 4085 *Anhydrol* PM 4084	*Filmex* C *Filmex* C, Anhydrous	GPC 190 Gov't Form C (3A) Anhydrous GPC Gov't Form C (3A)
Tecsol D, 95% *Tecsol* D, Anhydrous	*Anhydrol* PM 4080 *Anhydrol* PM 4176	*Filmex* D-1 *Filmex* D-1, Anhydrous	GPC 190 Gov't Form D (3A) Anhydrous GPC Gov't Form D (3A)
Tecsol D-2, 95% *Tecsol* D-2, Anhydrous	*Anhydrol* PM 4078 *Anhydrol* PM 4217	*Filmex* D-2 *Filmex* D-2, Anhydrous	GPC 190 Gov't Form D2 (3A) Anhydrous GPC Gov't Form D2 (3A)
Tecsol H	—	—	—

Table 6.128: Hoechst Celanese Alcohols *(42)*

Methanol

Physical Properties

Autoignition Temperature, °C	386
Boiling Point at 760 mm Hg, °C	64.65
Boiling Point at 760 mm Hg, °F	148.4
Coefficient of Thermal Expansion per °C 20°C	1.19×13^{-3}
Critical Pressure, atmospheres	78.7
Critical Temperature, °C	240.0
Dielectric Constant, 25°C	32.63
Electrical Conductivity at 25°C, mhos/cm	1.5×10^{-9}
Evaporation Rate (BuAc = 1)	2.0
Flammable Limits in Air	
(lower limit, vol %)	5.5
(upper limit, vol %)	36.0
Flash Point,	
Tag Open Cup, °F	60
Tag Closed Cup, °F	54
Freezing Point, °C	-97.8
Heat of Combustion, gas, 25°C, cal/gm	5683
Heat of Combustion liquid, 25°C, cal/gm	5420
Heat of Vaporization, cal/gm (at normal boiling point)	262.8
Molecular Weight	32.04
Refractive Index, n_D^{20}	1.3285
Reid Vapor Pressure, pounds per square inch	2.2
Solubility at 20°C, wt. %, in water	Complete
water in	Complete
Solubility in alcohol, ether or water	Complete
Specific Gravity, 20/20°C	0.7925
Specific Heat of Liquid,	
cal/gm/°C at 20°C	0.599
cal/gm/°C at 0°C	0.566
Surface Tension in Air at 20°C, dynes/cm	22.55
Vapor Density (air = 1)	1.11
Vapor Pressure, 20°C, mm Hg	96.0
Viscosity at 20°C, centipoise	0.614
Weight, pounds per gallon at 20°C (68°F)	6.59

n-Butanol
(Normal Butyl Alcohol, 1-Butanol, Butyric Alcohol, Propyl Carbinol, 1-Hydroxybutane)

Physical Properties

Autoignition Temperature, °C	367
Boiling Point at 760 mm Hg, °C	117.7
Boiling Point at 760 mm Hg, °F	243.9
Coefficient of Thermal Expansion per °C (20°C-40°C)	0.93×10^{-3}
Critical Pressure, atmospheres	43.6
Critical Temperature, °C	287
Dielectric Constant, at 25°C	16.1
Evaporation Rate (BuAc = 1)	0.45
Flammable Limits	
(lower limit, vol %)	1.4
(upper limti, vol %)	11.2
FlashPoint	
Tag Open Cup, °F	97
Tag Closed Cup, °F	84
Freezing Point, °C	−89.9
Heat of Combustion, cal/gm	8610
Heat of Formation, kcal/mole (liquid, 25°C)	−79.61
Heat of Fusion, cal/gm	29.9
Heat of Vaporization, cal/gm at normal boiling point	141.3
Molecular Weight	74.12
Refractive Index n_D^{20}	1.3992
Solubility at 20°C, wt % in water	7.8
water in	20.1
Specific Gravity, 20/20°C	0.8109
Specific Heat of Liquid, cal/gm°C at 20°C	0.563
Surface Tension in Air at 20°C dynes/cm	24.6
Vapor Density (air = 1)	2.57
Vapor Pressure, 20°C, mm Hg	4.4
Viscosity at 20°C, centipoise	2.9
Weight, pounds per gallon at 20°C (68°F)	6.75

Isobutanol
(Isobutyl Alcohol, Isopropylcarbinol, 2-Methyl-1-Propanol)

Physical Properties

Autoignition Temperature, °C	440
Boiling Point, 760 mm Hg, °C	108.0
760 mm Hg, °F	226.4
Coefficient Thermal Expansion per °C at 20°C, (10°-30°C)	0.95×10^{-3}
Critical Pressure, atmospheres	42.4
Critical Temperature, °C	227
Electrical Conductivity, mhos/cm, 25°C	8×10^{-3}
Evaporation Rate (n-BuAc = 1.0)	0.82
Flammable Limits (lower limit, vol %)	1.2
in Air @ 212°F (upper limit, vol %)	10.9
Flash Point, Tag Open Cup, °F	100
Tag Closed Cup, °F	82
Freezing Point, °C	-108
Heat of Combustion, cal/g	8610
Heat of Vaporization, cal/g at normal boiling point	138
Molecular Weight	74.12
Refractive Index, n_D^{20}	1.3959
Solubility, 20°C, wt % in water	8.5
water in	15.0
Specific Gravity, 20/20°C	0.8030
Specific Heat of Liquid, cal/gm/°C at 20°C	0.585
Surface Tension at 20°C, dynes/cm	22.94
Vapor Density (air = 1.0)	2.6
Vapor Pressure at 20°C, mm Hg	8.8
Viscosity, 20°C, centipoise	3.95
Weight, pounds per gallon at 20°C	6.68

n-Propanol
(Propylic Alcohol, Ethylcarbinol, Normal Propyl Alcohol)

Physical Properties

Autoignition Temperature, °C	371.1
Boiling Point at 760 mm Hg, °C	97.2
Boiling Point at 760 mm Hg, °F	207.0
Coefficient of Thermal Expansion per °C (0-94°C)	0.956×10^{-3}
Critical Pressure, atmospheres	49.9
Critical Temperature, °C	263.7
Distillation Range, °C	97.15 ± 1
Electrical Conductivity, mho/cm at 25°C	2×10^{-8}
Evaporation Rate (BuAc = 1)	1.3
Flammable Limits	
(lower limit, vol %)	2.2
(upper limit, vol %)	14.0
Flash Point, Tag Open Cup, °F	84
Tag Closed Cup, °F	71
Freezing Point, °C	-127.0
Heat of Combustion, cal/gm	8089.3
Heat of Formation, kcal/mole (vapor, 25°C)	-60.87
Heat of Fusion, cal/gm at -126.6°C	86.6
Heat of Vaporization, cal/gm at normal boiling point	188.0
Molecular Weight	60.10
Refractive Index, n_D^{20}	1.3854
Solubility at 20°C, in alcohol, ether, water	Complete
Specific Gravity, 20/20°C	0.8044
Specific Heat of Liquid, cal/gm/°C at 0°C	0.526
Surface Tension in Air at 20°C, dynes/cm	23.75
Vapor Density (air = 1)	2.07
Vapor Pressure, 20°C, mm Hg	13
Viscosity at 20°C, Centipoise	2.2
Weight, pounds per gallon at 20°C	6.70

Table 6.129: Proctor and Gamble Fatty Alcohols *(39)*

Chemical Properties	CO-1214	CO-1270	CO-1695	CO-1895	CO-1897	CO-1898	TA-1618
Hydroxyl Value	280-290 (285)	285-295 (289)	220-235 (228)	200-215 (204)	200-215 (206)	200-215 (207)	208-218 (211)
Acid Value	0.1 max (0.0)	0.10 max (0.0)	0.5 max (0.19)	0.5 max (0.1)	0.5 max (0.1)	0.5 max (0.1)	1.0 max (0.0)
Saponification Value	0.5 max (0.1)	0.5 max (0.1)	1.0 max (0.4)	2.0 max (0.6)	1.0 max (0.3)	1.0 max (0.3)	2.0 max (1.0)
Iodine Value	0.3 max (0.1)	0.2 max (0.04)	2.0 max (0.8)	2.0 max (0.8)	2.0 max (0.4)	2.0 max (0.25)	1.0 max (0.3)
Moisture (%)	0.10 max (0.04)	0.10 max (0.04)	0.10 max (0.05)	0.10 max (0.04)	0.10 max (0.03)	0.10 max (0.02)	0.10 max (0.03)
P&G Acid Heat Stability (% Transmittance @ 450 nm)	90 min (97)	90 min (99)					
Physical Properties							
Color-APHA	10 max (4)	10 max (3)	25 max (3-6)	25 max (8)	25 max (9)	25 max (10)	25 max (11)
Melting Point, (C)	(22)		47-50 (49)	56-60 (57)	56-60 (58)	56-60 (58)	(50)
Appearance	water white mobile liquid	water white mobile liquid	waxy white solid	waxy white solid	waxy white solid	waxy white solid	waxy white solid
Composition (% by GC)							
C8	0.3 max (0.1)						
C10	1.0 max (0.5)	1.5 max (0.7)					
C12	65.0 min (68.0)	68.0-74.0 (71.2)					(0.1)
C14	21.0-28.0 (26)	24.0-30.0 (27)	2.5 max (0.3)	(0.1)		(0.1)	1.5 max (0.6)
C16	4.0-8.0 (5.6)	1.5 max (0.6)	95.0 min (96.5)	2.5 max (0.8)	(0.5)	1.5 max (0.6)	23.0-33.0 (30)
C18	0.5 max (0.0)		(2.5)	95.0-98.0 (96.6)	97.5 min (98.2)	98.0-99.0 (98.6)	65.0 min (69)
C20				0.2-1.4 (0.6)	2.0 max (0.3)	0.5 max (0.1)	1.5 max (0.1)
Hydrocarbon	1.0 max (0.3)	1.0 max (0.4)	1.5 max (0.2)	1.5 max (0.3)	1.5 max (0.2)	1.5 max (0.1)	1.5 max (0.1)
CAS No.	67762-41-8	67762-41-8	36653-82-4	112-92-5	112-92-5	112-92-5	67762-30-5

Table 6.130: Shell Chemical Alcohols *(14)*

Typical Properties of the Alcohols

	Isopropyl Alcohol	Isobutyl Alcohol	Normal Butyl Alcohol	Secondary Butyl Alcohol	Methyl Isobutyl Carbinol	Diacetone Alcohol	2-Ethyl Hexanol
Molecular Weight	60.096	74.124	74.124	74.124	102.178	116.162	130.231
Specific Gravity (Apparent)							
60/60 °F	0.7893	0.8060	0.8135	0.8109	0.8107	0.9441	0.8362
20/20 °C	0.7864	0.8033	0.8109	0.8080	0.8078	0.9409	0.8338
25/25 °C	0.7832	0.8006	0.8082	0.8050	0.8048	0.9374	0.8312
Wt. per U.S. Gallon (in air)							
60 °F	6.574	6.712	6.775	6.753	6.751	7.863	6.964
20 °C	6.544	6.685	6.748	6.724	6.722	7.830	6.938
25 °C (VOC content)	6.510	6.654	6.718	6.691	6.689	7.792	6.909
Boiling Point at 760 mm							
°C	82.33	107.89	117.73	99.50	131.8	169.2	184.8
°F	180.19	226.20	243.91	211.10	269.24	336.6	364.64
Boiling Point Change °C/mm at 760 mm	0.0325	0.0360	0.0370	0.0349	0.0407	0.075	0.049
Vapor Pressure at 20 °C, mm	32.8	8.77	4.3	12.5	2.2	0.81	0.20
Freezing Point at 760 mm, °C	-88.43	-108	-89.3	-114.7	-90	-44	< -75
Refractive Index, n_D^{20}	1.37720	1.3959	1.3993	1.3969	1.4110	1.4234	1.4328
Heat of Vaporization cal/g at 760 mm	159.23	139	141.5	134.41	99.87	90	93
Heat of Fusion at Melting Pt. cal/g	21.37	—	—	—	—	—	—
Specific Heat (liquid) cal/g °C	0.541	0.581	0.564	0.540	0.52	0.62	0.564
Flash Point, Tag Open Cup °F, Approx.	60	100	110	80	131	135	185
Flash Point, Tag Closed Cup °F, Approx.	53	86	98	72	103	126	166
Autoignition Temp. °F, Approx.	750	800	650	761	—	—	—
Flammable Limits in Air %v of Compound							
Upper	12	10.9	11.2	9.0	5.5	—	—
Lower	2.0	1.7	1.4	1.7	1.0	—	—
Solubility, %wt							
in water at 20 °C	complete	8.7	7.7	15.4	1.6	complete	0.07
water in at 20 °C	complete	15	20.1	65.1	6.3	complete	2.6
Azeotrope with Water							
% w compound	87.70	67	57.5	72.7	55.6	12.7	20
Boil Pt. at 760 mm, °C	80.16	89.8	92.7	87.5	94.3	98.8	99.1
Viscosity, cps							
at 15 °C	2.859	—	—	—	—	—	—
at 20 °C	—	3.98	2.96	3.78	—	—	8.14
at 25 °C	2.4	3.4	2.6	2.9	3.8	2.9	7.7
at 30 °C	—	—	—	—	—	—	—
Surface Tension, dyne/cm at 20 °C	21.35	22.8	24.6	23.0	22.8	28.9	—

Table 6.131: Union Carbide Alcohols *(19)*

Product	Formula	Molecular Weight	Relative Evaporation Rate nBuAc = 1	Vapor Pressure at 20°C, mm Hg	Density at 20°C, lb/gal	Gravity at 20/20°C	Specific Hoy Solubility Parameters Total	Hydrogen Bonding	Polar	Non-Polar
Alcohols										
Amyl Alcohol, Primary	$C_5H_{11}OH$ (Mixed Isomers)	88.15	0.18	1.6	6.79	0.816	11.1	7.2	4.4	7.3
n-Butanol	C_4H_9OH	74.12	0.44	4.2	6.75	0.811	11.6	7.6	4.9	7.3
Diisobutyl Carbinol	$C_9H_{19}OH$ (Mixed Isomers)	144.26	0.07	0.1	6.76	0.812	9.0	4.5	3.3	7.0
Ethanol, 95%[d]	C_2H_5OH	46.07	3.00	41.4	6.75	0.811	12.8	9.8	5.5	6.2
2-Ethylhexanol	$C_4H_9CH(C_2H_5)CH_2OH$	130.23	0.10	0.1	6.94	0.834	10.2	5.9	3.8	7.4
Isobutanol	$CH_3CH(CH_3)CH_2OH$	74.12	0.74	7.2	6.68	0.803	11.2	7.3	4.8	7.1
Isopropanol, Anhydrous	$CH_3CH(CH_3)OH$	60.10	2.90	33.0	6.55	0.786	11.5	7.8	4.8	6.9
Methyl Amyl Alcohol	$CH_3CH(CH_3)CH_2CH(CH_3)OH$	102.18	0.43	3.7	6.72	0.808	9.0	5.1	3.7	6.4
2-Methyl Butanol	$CH_3CH_2CH(CH_3)CH_2OH$	88.15	0.24	2.0	6.81	0.816	11.1	6.9	4.5	7.4
n-Pentanol	$C_5H_{11}OH$	88.15	0.18	1.6	6.79	0.816	10.8	7.0	4.4	7.0
n-Propanol	C_3H_7OH	60.10	1.30	14.9	6.71	0.805	12.2	8.6	5.2	6.9

Alcohols	Viscosity, at 20°C, cP	Surface Tension at 20°C, dynes/cm	Boiling Point at 760 mm Hg, °C	Solubility at 20°C, Percent by Wt In Water	Water In	Flash Point, Tag Closed Cup, °F	Electrical Resistance[a], Megohms	Odor Detection Threshold[b] ED50, ppm	Title III Listed Hazardous Air Pollutant[c]	CAS Registration Number
Amyl Alcohol, Primary	4.0	25.7	137.9	1.7	9.2	113			No	Mixture
n-Butanol	2.9	24.8	117.7	7.7	20.0	95	0.18	2.78	No	71-36-3
Diisobutyl Carbinol	13.9	26.0	178.0	0.06	1	149			No	Mixture
Ethanol, 95%[d]	1.2	22.5	80.0	Complete		62			No	64-17-5
2-Ethylhexanol	9.0	26.8	184.6	0.07	2.6	162			No	104-76-7
Isobutanol	3.9	23.0	107.9	8.5	15.0	82	0.18		No	78-83-1
Isopropanol, Anhydrous	2.4	21.4	82.3	Complete		53			No	67-63-0
Methyl Amyl Alcohol	5.1	23.1	131.7	1.7	5.8	102			No	108-11-2
2-Methyl Butanol	5.0	25.5	128.7	2.2	8.3	110			No	137-32-6
n-Pentanol	4.0	25.7	137.9	2.6	9.5	119			No	71-41-0
n-Propanol	2.2	23.8	97.2	Complete		76	0.18		No	71-23-8

ALLYL ALCOHOL

Table 6.132: Physical Properties of Allyl Alcohol *(31)*

Boiling point at 760 mm	96.90°C
Coefficient of expansion at 20°C	0.00101 per °C
Color (Pt-Co, Hazen)	15 max.
Critical temperature	271.9°C
Distillation range, IBP	95°C, min.
DP	98°C, min.
Fire hazard	Dangerous when exposed to heat or flame
Flash point (Open cup)	90°F
(Closed cup)	72°F
Freezing point	Becomes a glass at -190°C
Heat of combustion (vapor)	442.4 kg cal/gm mole
Ignition temperature in air	443°C
in oxygen	348°C
Latent heat of vaporization at 760 mm	9550 cal/mole (295 BTU/lb)
MAC	5 ppm in air
Melting point	-129°C
Molecular weight	58.078
Purity	98.0% by wt., min.
Refractive index at 20°C, n_D	1.4134
Specific gravity at 25/25°C	0.8501
Specific heat, Cp for liquid, 20-95°C	0.665 g cal/g-°C
Surface tension at 20°C	25.68 dynes/cm
Toxicity	Highly toxic by inhalation and ingestion
Vapor pressure at 20°C	17.3 mm
Viscosity at 30°C	0.01072 poises
Water	0.3% by wt., max.
Weight per gallon at 20°C	7.11 lbs.

Table 6.133: Azeotropes of Alkyl Alcohol *(31)*

ALLYL ALCOHOL FORMS BINARY AZEOTROPES WITH

%		B. P. of Azeotrope °C
70	Allyl ether	89.8
82.6	Benzene	76.8
70	1-Bromobutane	89.5
91	1-Bromopropane	69.4
17.5	Chlorobenzene	96.5
85	1-Chlorobutane	74.5
71	1-Chloro-3-methylbutane	88.3
93	1-Chloro-2-methylpropane	67.0
80	Cyclohexane	74.0
78.3	Cyclohexene	76.3
89	Diethoxymethane	87.0
46	Ethyl propionate	93.2
55	Ethyl sulfide	85.1
63	Heptane	84.5
95.5	Hexane	65.5
48	Isobutyl formate	93.0
64	3-Methyl-2-butanone	93.5
49	Methyl butyrate	94.7
77	Methyl carbonate	86.4
58	Methylcyclohexane	85.0
72	Methyl isobutyrate	89.8
32	Octane	93.4
30	2-Pentanone	96.0
28	3-Pentanone	96.0
48	Propyl acetate	94.6
26	Propyl alcohol	96.7
70	Propyl ether	85.7
50	Toluene	91.5

CROTYL ALCOHOL

Crotyl alcohol is a clear, stable liquid with a straight-chain, bifunctional molecular structure, $CH_3-CH=CH-CH_2OH$. A highly reactive compound, crotyl alcohol should find use in the manufacture of agricultural chemicals, plastics and polymer additives, varnish ingredients, and pharmaceuticals.

The bifunctionality or two reactive points — hydroxy group and point of unsaturation — account for the high degree of chemical reactivity of crotyl alcohol. The hydroxy group undergoes such reactions as esterification and etherification; whereas the double bond enters into polymerization and addition reactions.

Table 6.134: Physical Properties of Crotyl Alcohol *(41)*

Empirical formula	C_4H_8O
Molecular weight (theoretical)	72.10
Physical form	Clear liquid
Color, APHA, ppm.	15
Purity, by gas chromatography, %	97-98
Acidity, as crotonic acid, %	0.049
Boiling range, 760 mm., °C.	
Initial boiling point	121
Dry point	126
Specific gravity, 20°/20°C.	0.8550
Bulk density, lb./gal., 20°C.	7.12
Flash point, Tag Open Cup, °F.	113 (45°C.)
Fire point, Tag Open Cup, °F.	113 (45°C.)
Isomer concentration (approximate)	3:1 trans:cis
Viscosity, 75°F. (23.9°C.), cs.	32.7
Solubility, 25°C., wt. %	
in water water in	Completely miscible with water in all proportions
ethyl alcohol	miscible
acetone	miscible

METHYLBUTYNYL ALCOHOL

Methylbutynol, 2-Methyl-3-Butyn-2-ol $HCCCOH(CH_3)_2$

Methylbutynyl alcohol is a tertiary acetylenic alcohol with an isoprenoid structure.

Table 6.135: Physical Properties of Methylbutynyl Alcohol *(31)*

Boiling point	104 - 105°C
Fire hazard	Dangerous when exposed to heat or flame
Flash point, Tag open cup	87.4°F
Freezing point	2.6°C
Refractive index at 20°C, n_D	1.4211
Specific gravity, 20/20°C	0.8672
Surface tension at 25°C	23.8 dynes/cm (pure) 41.7 dynes/cm (5% in water)
Vapor pressure at 20°C	12 mm
at 52°C	80 mm
Weight per gallon	7.24 lbs

METHYLPENTYNYL ALCOHOL

Table 6.136: Physical Properties of Methylpentynyl Alcohol *(31)*

Boiling point	121 - 122°C
Fire hazard	Moderate
Flash point, Tag open cup	101.3°F
Freezing point	-30.6°C
Refractive index at 20°C, n_D	1.4318
Solubility in water at 25°C	12.8 g (100 g)
Specific gravity at 20/20°C	0.8721
Surface tension at 25°C	23.8 dynes/cm (pure) 34.1 dynes/cm (5% in water)
Vapor pressure at 20°C at 68°C	4 mm 90 mm
Weight per gallon	7.28 lbs

HIGHER UNSATURATED ALCOHOLS

Table 6.137: Unsaturated Aliphatic Alcohols *(69)*

Systematic Name	Common Name	Empirical Formula	Mol. Wt.	Double Bonds	* Boiling Pt. oC.
9:10-Dodecenol	Lauroleyl	$C_{12}H_{23}OH$	184.31	1	157/15 mm
9:10-Tetradecenol	Myristoleyl	$C_{14}H_{27}OH$	212.36	1	
9:10-Hexadecenol	Palmitoleyl	$C_{16}H_{31}OH$	240.41	1	
9:10-Octadecenol	Oleyl	$C_{18}H_{35}OH$	268.46	1	208-209/15 mm
9:10-Eiscosenol	Gadoleyl	$C_{20}H_{39}OH$	296.51	1	
13:14-Docosenol	Erucyl	$C_{22}H_{43}OH$	324.57	1	240.5-241.5/10 mm
9:10, 12:13-Octadecadienol	Linoleyl	$C_{18}H_{33}OH$	266.45	2	148-150/1 mm
9:10, 12:13, 15:16-Octadecatrienol	Linolenyl	$C_{18}H_{31}OH$	264.43	3	
9:10, 11:12, 13:14-Octadecatrienol	Elaeostearyl	$C_{18}H_{31}OH$	264.43	3	
9:10-Octadecen-1,12-diol	Ricinoleyl	$C_{18}H_{34}(OH)_2$	284.47	1	
5:6, 8:9, 11:12, 14:15-Eicosatetraenol	Arachidonyl	$C_{20}H_{33}OH$	290.31	4	
4:5, 8:9, 12:13, 15:16, 19:20-Docosapentenol	Clupanodonyl	$C_{22}H_{35}OH$	316.0	5	

* Ralston, A. W., "Fatty Acids and Their Derivatives", p. 733.
* Hilditch, T. A., "The Chemical Constitution of Natural Fats".
* Brockelsby, H. P., "The Chemistry and Technology of Marine Oils with Particular Reference to Those of Canada". p. 90.

DIACETONE ALCOHOL

Table 6.138: Physical Properties of Diacetone Alcohol *(31)*

Acidity as acetic acid	0.01% by wt, max.
Azeotrope with water: boiling point, 760 mm diacetone	 98.8°C 12.7% by wt
Boiling point, 760 mm	169.2°C
Coefficient of expansion at 55°C	0.00100
Fire hazard	Moderate
Flash point, Open cup	155°F
Freezing point	-42.8°C
Heat of vaporization, 1 atm.	162 Btu/lb
Hydrocarbon solubility	Complete
MAC	50 ppm in air
Molecular weight	116.16
Refractive index at 20°C, n_D	1.4232
Relative evaporation rate (n-butyl acetate = 100)	14
Specific gravity at 20°C	0.9406
Specific heat at 15°C	0.500 cal/gm/°C
Toxicity	Slight
Vapor pressure at 20°C	0.97 mm
Viscosity at 20°C	3.2 cps
Water at 20°C	Miscible without turbidity with 19 vol. of 60° Bé gasoline
Weight per gallon at 20°C	7.82 lbs

2-MERCAPTOETHYL ALCOHOL

Table 6.139: Physical Properties of 2-Mercaptoethyl Alcohol *(31)*

Boiling point at 760 mm	156.9°C
50 mm	83°C
10 mm	53°C
Coefficient of expansion at 55°C	0.00080
Fire hazard	Moderate
Flash point, Open cup	170°F
Heat of vaporization	257 Btu/lb
Molecular weight	78.13
Refractive index at 20°C, n_D	1.5011
Relative evaporation rate (n-butyl acetate = 100)	13
Solubility in water at 20°C	Complete
Solubility of water in, at 20°C	Complete
Specific gravity at 20/20°C	1.1168
Vapor pressure at 20°C	1.2 mm
Viscosity (absolute) at 20°C	3.4 cps.
Toxicity	Moderate (acute local)
Weight per gallon at 20°C	9.30 lbs

2-ETHYLSULFONYLETHYL ALCOHOL

Table 6.140: Physical Properties of 2-Ethylsulfonylethyl Alcohol *(37)*

Acidity as acetic acid	0.25% max.
Boiling range at 2.5 mm	155 to 156°C
Fire hazard	Slight
Fire point	406°F
Flash point, Tag open cup	370°F
Moisture content	1.5% max.
Molecular weight	138.19
Refractive index at 26°C, n_D	1.4679
Set point	40.5 to 42.5°C
Specific gravity at 45/20°C	1.252 to 1.258 g/ml
Toxicity	Slight
Viscosity at 60°C	12.8 cps.

1,1,1-TRIFLUOROETHYL ALCOHOL

Table 6.141: Trifluoroethanol Physical Properties *(25)*

Molecular Weight (CF_3CH_2OH)	100.04
Boiling Point, °C	73.6
Melting Point, °C	−45.0
Flash Point (Open Cup), °F	105
(Closed Cup), °F	92
Fire Point	None
Density, 25°C/4°C	1.3823
Refractive Index, n_D^{20}	1.2907
Critical Temperature, °C	227
Critical Pressure, psia	715
Heat of Vaporization, Btu/lb.	149
Heat of combustion[16], kcal./mol	−211.9
Vapor Pressure vs. Temperature, (mm. Hg., °K)	$\log P = -\frac{1910}{T} + 8.39$
Thermal Conductivity, Btu/hr. ft. @ 104°F	0.071
Viscosity, centistokes, 100°F	0.90
Ionization Constant K_a[2]	4.3×10^{-13}
Dipole Moment[17], μ(D)25°C	2.03
Dielectric Constant[18], ε(25°C)	26.14

Table 6.142: Polymer Solubilities in Trifluoroethanol *(25)*

POLYMER SOLUBILITIES IN TRIFLUOROETHANOL

solubility	nylon 6/6	nylon 6	nylon 6/10	Zytel® 61*
g./100 g. solution at b.p. (ca 80 °C)	13	>20	14	>26
g./100 g. solution at 24 °C	3	11	3	>26
Insoluble Polymers at b.p.:	Delrin®, Lexan®, Mylar®, Polyethylene (high and low density). Polypropylene, Orlon®			
Other Soluble Polymers:	Polymethacrylate (>27 wt. % at 24 °C): Cellulose Acetate (>28 wt. % at 24 °C): Polyvinyl Acetate (>24 wt. % at 24 °C).			
Slightly soluble:	Nylon 11 (0.2 wt. %)			

*a duPont "soluble" nylon

Table 6.143: Salt Solubility (wt. %) in Trifluoroethanol at 25°C *(25)*

Salts

Inorganic salts are slightly soluble trifluoroethanol containing 0.2% water. The same salts are bout 2 to 3 times more soluble in the alcohol containing 5% water. This combination of alcohol and water is convenient for conductometric titrations and organic ionic reactions.

SOLUBILITY (WT.%) IN TRIFLUOROETHANOL AT 25°C

Water Content	LiCl	NaCl	NaF	KI	KBr	$CaCl_2$
0.2%	2.3	0.03	0.007	0.9	0.3	0.04
5.0%	4.2	0.08	0.02	2.1	0.6	0.12

Table 6.144: Solubility of Gases in Trifluoroethanol at 27°C *(25)*

Gases

The simple gases have solubilities in trifluoroethanol which are similar to their solubilities in water.

SOLUBILITY OF GASES IN TRIFLUOROETHANOL AT 27°C
(ml. of gas/ml. of liquid)

N_2	O_2	CO_2
0.06	0.13	1.8

Table 6.145: Vapor Pressure vs. Temperature *(25)*

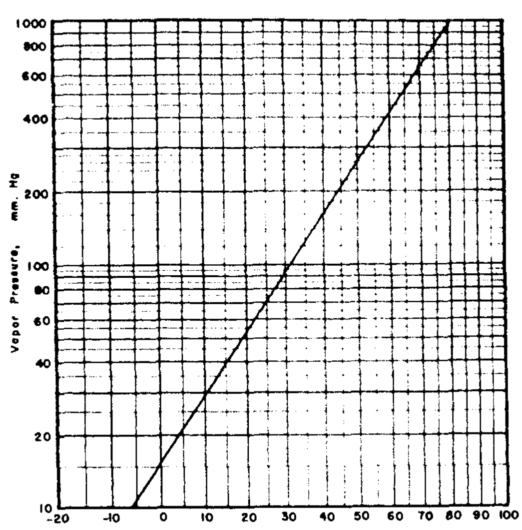


Table 6.146: Freezing Point: Trifluoroethanol-Water *(25)*

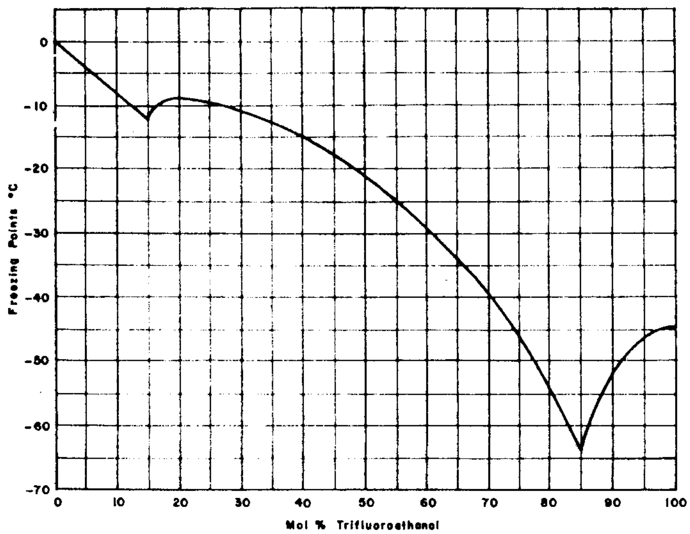
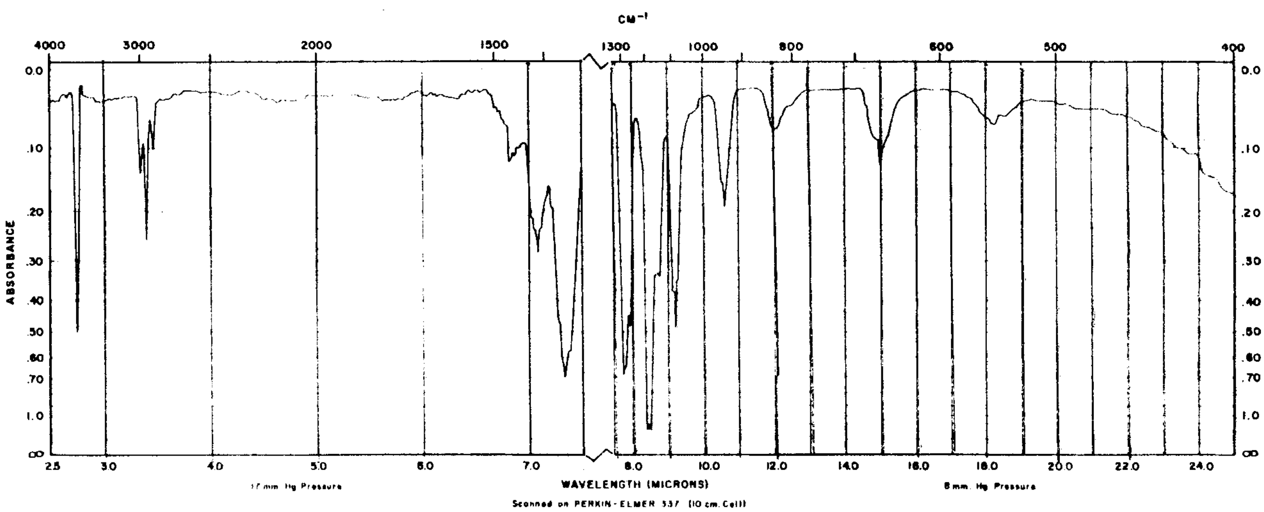


Table 6.147: Infrared Spectrum *(25)*



1H,1H,3H-TETRAFLUORO-1-PROPYL ALCOHOL

Table 6.148: Physical Properties of 1H,1H,3H-Tetrafluoro-1-Propyl Alcohol *(31)*

Acid number	0.82
Boiling point at 760 mm	109 - 110°C
Density at 20°C	1.4853 g/ml
Distillation range at 760 mm	90% between 99.5° and 108.5°C
Fluorine content	57.5%
Formula weight	132.06
Hydroxyl number	398
Melting point	-15°C
Moisture content	0.40%
Purity	> 95%
Refractive index at 20°C, n_D	1.3197
Surface tension at 20°C	27.6 dynes/cm

1H,1H,5H-OCTAFLUORO-1-PENTYL ALCOHOL

Table 6.149: Physical Properties of 1H,1H,5H-Octafluoro-1-Pentyl Alcohol *(31)*

Acid number	0.70
Boiling point at 760 mm	140 - 141°C
Density at 20°C	1.6647 g/ml
Distillation range, ASTM, at 760 mm	90% between 133.0° and 141.0°C
Fluorine content	65.5%
Formula weight	232.08
Hydroxyl number	224
Moisture content	0.08%
Purity	> 95%
Refractive index at 20°C, n_D	1.3190
Surface tension at 20°C	24.5 dynes/cm

BENZYL ALCOHOL

Table 6.150: Physical Properties of Benzyl Alcohol *(31)*

Acidity as benzoic acid	0.15% max.
Aldehyde as benzaldehyde	0.50% max.
Boiling point	205.3°C
Chlorine as benzyl chloride	0.15% max.
Dielectric constant	1.66
Distillation range, Ibp	195°C min.
5%	204°C
90%	207°C
95%	210°C max.
Electrical conductivity at 25°C	18 x 10^{-7} recip. ohms.
Fire hazard	Slight
Flash point (Open cup)	213°F
Freezing point	-15.3°C
Heat of combustion	893 kg cal/mole
Latent heat of evaporation at 204.25°C	111.58 gm cal/gm
Molecular weight	108.13
Refractive index at 20°C, n_D	1.5334-1.5397
Solubility in water	1 part in 30 parts of water
Specific gravity at 25/25°C	1.044-1.058
Specific heat at 15-20°C	0.5402 cal/gm
Surface tension (c.g.s. units)	39.71
Toxicity	Slight
Vapor pressure at 30°C	0.100 mm
Viscosity at 20°C	0.05582 cps.
Weight per gallon at 20°C	9.78 lbs.

Table 6.151: VELSICOL Benzyl Alcohol *(59)*

Benzyl Alcohol, Reagent Grade

Benzyl Alcohol is a clear, colorless liquid with a mild, pleasant aromatic odor. It is a primary alcohol with reactive methylene and nuclear hydrogen. The reagent grade is a high purity material with analytical utility.

SPECIFICATIONS	
Assay, (G.C.), % minimum	99.0
Solubility, in 25 ml water at 25°C, g	1
Benzaldehyde content (U.V. determination), % maximum	0.03
Halogen (Beilstein Test)	Negative

TYPICAL PROPERTIES	
Boiling Point,	
5 mm Hg, °F/°C	177.8°/81°
760 mm Hg, °F/°C	401°/205°
Vapor Pressure, mm Hg	
at 86°F/30°C	0.1
at 212°F/100°C	13.3
Melting Point, °F/°C	-5°/-15°
Specific Gravity, 25°/25°C	1.042 - 1.047
Refractive Index, 25°C	1.5390 - 1.5410
Vapor Density (air=1)	3.72

FURFURYL ALCOHOL

Table 6.152: Physical Properties of Furfuryl Alcohol *(46)*

PHYSICAL PROPERTIES

General Properties

Molecular Weight	98.10
Boiling Point (at 760 mm Hg)	
°C	170
°F	338
Freezing Point, metastable crystalline form	
°C	−29
°F	−20.2
Freezing Point, stable crystalline form	
°C	−14.63
°F	5.7
Density (at 20°C, 68°F), g/cm³	1.1285
Specific Gravity, 20/20°C	1.1351
Refractive Index	
n_D^{20}	1.4868-1.4870
n_D^{25}	1.4843-1.4845
Vapor Density (air = 1)	3.38
Vapor Pressure (at 31.8°C, 89.2°F), mm Hg	1

Also see Table I & Figure B

Thermodynamic Properties

Heat of Vaporization, cal/g	122
Heat Capacity, cal/g-°C	
liquid at −20°C	0.450
liquid at 0°C	0.472
liquid at 25°C	0.502
stable crystalline form at −40°C	0.256
stable crystalline form at −20°C	0.278
Thermal Conductivity, kcal/m-hr-°C	0.154
Heat of Combustion, kcal/gmole	
at constant volume	608.9
at constant pressure	609.2
Heat of Formation, liquid, kcal/gmole	−66.06
Heat of Fusion, stable crystalline form, cal/g	31.8
Thermal Expansion Coefficient*	
β/°C (−17.8 to 37.8°C)	8.52×10^{-4}
β/°F (0 to 100°F)	4.53×10^{-4}

$$^*\beta = \frac{\rho_1^2 - \rho_2^2}{2(t_2 - t_1)\rho_1 \rho_2}$$ (Note: ρ = specific gravity, t = temperature)

Fluid Properties

Viscosity (at 25°C, 77°F), cps	5
Surface Tension (at 25°C, 77°F), dynes/cm	38.2
Furfuryl Alcohol-Water Azeotrope (at 760 mm Hg)	
Boiling Point of Vapor	
°C	99
°F	210.2
Composition, wt %	
Furfuryl Alcohol	ca 9
Water	ca 91

Other Properties

Physical State	Liquid
Color	Colorless to Yellow
Odor	Mild & Characteristic
Chemical Oxygen Demand, lb/lb FA	1.75
Biochemical Oxygen Demand (5 days, 20°C), lb/lb FA	0.81
Dipole Moment, e.s.u.	1.92×10^{18}
Solubility Parameter, $(cal/cm^3)^{1/2}$	12.5
Solubility in	
Water	∞
Alcohol	∞
Ether	∞

Flammability Properties of Commercial QO® FA® Furfuryl Alcohol

Flash Point	
Tagliabue, closed cup	
°C	77
°F	170
Pensky-Martens, closed cup	
°C	83
°F	182

(Based on flash point, furfuryl alcohol is classified as a Combustible Liquid Class IIIA.*)

Flammability Limits (in dry air at 72.5−122°C)	
% by volume	
Lower limit	1.8
Upper limit	16.3
Ignition Temperature	
In air	
°C	391
°F	736
In oxygen	
°C	364
°F	687
DOT Label Required	
U.S.	none**
International	See IMCO regulations

*Refers to Code 29 CFR 1910.106 of Federal Regulations.

**When shipping via UPS, consult their *Guide For Shipping Hazardous Materials Via UPS.*

QO® FA® Furfuryl Alcohol Specifications*

Furfuryl Alcohol, Assay, wt %, Minimum	98.0
Moisture, wt %, Maximum	0.3
Furfural, wt %, Maximum	0.7
Cloud Point, °C, Maximum**	10.0

*Methods available upon request.

**The cloud point of furfuryl alcohol is determined by diluting 15 ml of the alcohol with 30 ml of water and cooling the clear solution until it becomes definitely cloudy. The solution is then allowed to warm up with stirring until it is just clear. At this point, cooling produces an immediate cloudiness; this temperature is recorded as the cloud point (9).

Table 6.153: Vapor Pressure of Furfuryl Alcohol *(46)*

Temperature °C	Temperature °F	Pressure mm Hg	
31.8	89.2	1	△
40	104	1.8	○
55.5	131.9	5.5	□
56.0	132.8	5	△
60	140	6.3	○
68.0	154.4	10	△
75.5	167.9	16	□
80	176	20.3	○
81.0	177.8	20	△
95.5	203.9	44	□
95.7	204.3	40	△
100	212	53.5	○
104.0	219.2	60	△
108.5	227.3	78	□
115.9	240.6	100	△
120	248	127.4	○
129.5	265.1	194	□
133.1	271.6	200	△
140	284	271.0	○
144.0	291.2	343	□
151.8	305.3	400	△
157.0	314.6	522	□
170.0	338	760	△

□ Quaker Oats Chemicals, Inc., Research Laboratory, unpublished data.
△ D.R. Stull, *Ind. & Eng. Chem.,* 39, 517, 1947
○ G.S. Parks, private communication

Table 6.154: Pounds per Gallon of Furfuryl Alcohol at Various Temperatures *(46)*

T, °F	T, °C	lbs/gal	T, °F	T, °C	lbs/gal
0	−17.78	9.7380	51	10.56	9.5182
1	−17.22	9.7337	52	11.11	9.5139
2	−16.67	9.7294	53	11.67	9.5096
3	−16.11	9.7251	54	12.22	9.5053
4	−15.56	9.7208	55	12.78	9.5010
5	−15	9.7165	56	13.33	9.4967
6	−14.44	9.7122	57	13.89	9.4924
7	−13.89	9.7079	58	14.44	9.4881
8	−13.33	9.7036	59	15	9.4838
9	−12.78	9.6992	60	15.56	9.4795
10	−12.22	9.6949	61	16.11	9.4752
11	−11.67	9.6906	62	16.67	9.4708
12	−11.11	9.6863	63	17.22	9.4665
13	−10.56	9.6820	64	17.78	9.4622
14	−10	9.6777	65	18.33	9.4579
15	− 9.44	9.6734	66	18.89	9.4536
16	− 8.89	9.6691	67	19.44	9.4493
17	− 8.33	9.6648	68	20	9.4450
18	− 7.78	9.6605	69	20.56	9.4407
19	− 7.22	9.6562	70	21.11	9.4364
20	− 6.67	9.6518	71	21.67	9.4321
21	− 6.11	9.6475	72	22.22	9.4278
22	− 5.56	9.6432	73	22.78	9.4234
23	− 5	9.6389	74	23.33	9.4191
24	− 4.44	9.6346	75	23.89	9.4148
25	− 3.89	9.6303	76	24.44	9.4105
26	− 3.33	9.6260	77	25	9.4062
27	− 2.78	9.6217	78	25.56	9.4019
28	− 2.22	9.6174	79	26.11	9.3976
29	− 1.67	9.6131	80	26.67	9.3933
30	− 1.11	9.6087	81	27.22	9.3890
31	− 0.56	9.6044	82	27.78	9.3847
32	0	9.6001	83	28.33	9.3803
33	0.56	9.5958	84	28.89	9.3760
34	1.11	9.5915	85	29.44	9.3717
35	1.67	9.5872	86	30	9.3674
36	2.22	9.5829	87	30.56	9.3631
37	2.78	9.5786	88	31.11	9.3588
38	3.33	9.5743	89	31.67	9.3545
39	3.89	9.5700	90	32.22	9.3502
40	4.44	9.5657	91	32.78	9.3459
41	5	9.5613	92	33.33	9.3416
42	5.56	9.5570	93	33.89	9.3373
43	6.11	9.5527	94	34.44	9.3329
44	6.67	9.5484	95	35	9.3286
45	7.22	9.5441	96	35.56	9.3243
46	7.78	9.5398	97	36.11	9.3200
47	8.33	9.5355	98	36.67	9.3157
48	8.89	9.5312	99	37.22	9.3114
49	9.44	9.5269	100	37.78	9.3071
50	10	9.5226			

Table 6.155: Density of Furfuryl Alcohol-Water Solutions as a Function of Composition (at 25°C, 77°F) *(46)*

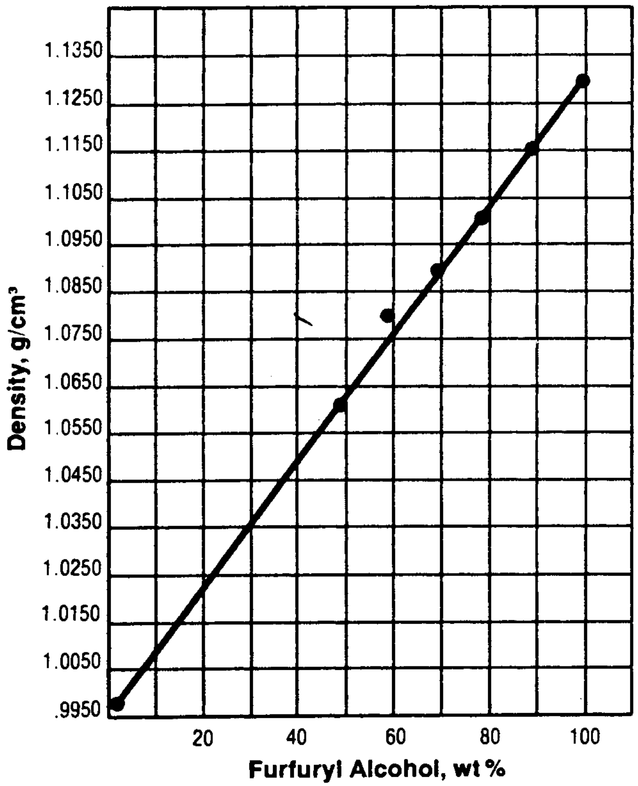


Table 6.156: Vapor Pressure of Furfuryl Alcohol as a Function of Temperature *(46)*

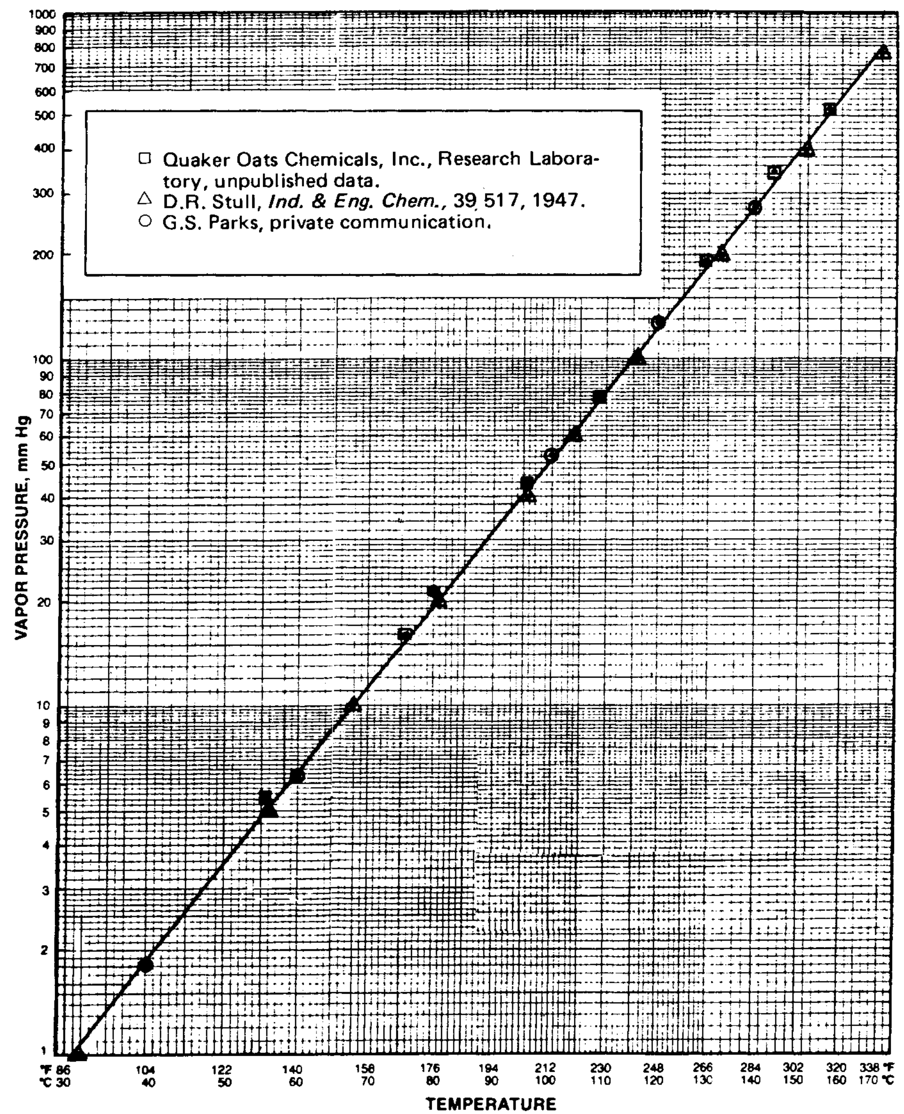


Table 6.157: Solubility of Liquid Organic Compounds in Furfuryl Alcohol (at 25°C, 77°F) (46)

Compound	5 cc/5 cc Furfuryl Alcohol	5 cc/10 cc Furfuryl Alcohol
Acid, dichloroacetic, C.P.	R	
Acid, lactic, U.S.P.	S	
Acid, valeric	S	
Alcohol, amyl	S	
Alcohol, benzyl, tech.	S	
Alcohol, ethyl	S	
Alcohol, isoamyl, tech.	S	
Alcohol, isobutyl, C.P.	S	
Alcohol, isopropyl, tech.	S	
Alcohol, propyl	S	
Aniline	S	
1,2-Butanediol	S	
Chloroform, U.S.P.	S	
Crotonaldehyde, tech.	S	
o-Dichlorobenzene	S	
Dichloroethyl ether, tech.	S	
Diethylaniline, tech.	S	
Diethyl carbonate	S	
Diethylene glycol	S	
Diethylene glycol dioleate	S	
Diethylene glycol monobutyl ether, tech.	S	
Diethyl phthalate, C.P.	S	
Diethyl sulfate, tech.	R	
N,N-Dimethylaniline, tech.	S	
Dimethyl sulfate	R	
Ether, ethyl	S	
Ether, isopropyl	S	
Ethyl acetate, tech.	S	
Ethyl acetoacetate	S	
N-Ethyl-N-benzylaniline	SS	S
Ethyl bromide	S	
Ethylchlorocarbonate	R	
Ethylene chlorohydrin	SS	SS
Ethylene dichloride	S	
Ethylene glycol monobutyl ether, tech.	S	
Glycerol, U.S.P.	S	
Methyl acetate, tech.	S	
Methyl ethyl ketone	S	
Nitrobenzene	S	
o-Nitrotoluene, tech.	S	
Oil, lard	I	I (S at 125°C)
Oil, linseed	SS	SS (S at 120°C)
Oil, neatsfoot	I	I (S at 120°C)
Oil, peanut	I	I (S at 125°C)
Oil, rapeseed	I	I (S at 120°C)
Oil, Turkey red	S	
Oil, whale	I	I (S at 125°C)
Paraldehyde, U.S.P.	S	
Pyridine, tech.	S	
1,1,2,2-Tetrachloroethane, tech.	S	
o-Toluidine, tech.	S	
Xylene	S	

Table 6.158: Solubility of Solid Organic Compounds in Furfuryl Alcohol (at 25°C, 77°F) (46)

Compound	1 g/5 cc Furfuryl Alcohol	1 g/10 cc Furfuryl Alcohol
Acid, acetylsalicylic, U.S.P.	S	
Acid, anthranilic	S	
Acid, benzoic, U.S.P.	S	
Acid, citric, U.S.P.	SS	S
Acid, monochloroacetic	S	
Acid, naphthionic, tech.	I	I (R at 115°C)
Acid, oxalic, tech.	I	R
Acid, stearic	SS	SS (S at 95°C)
Acid, sulfanilic	I	I (R at 115°C)
Acid, tannic	SS	SS (SS at 125°C)
Acid, tartaric, U.S.P.	I	I (SS at 125°C)
Acid, trichloroacetic	R	
Anthracene, tech.	I	SS (S at 110°C)
Anthraquinone	I	I (S at 130°C)
Benzidine	SS	S–R
3-Bromo-d-camphor	S	
Carbazole	I	I (S at 120°C)
Casein	I	I (I at 125°C)
Chloral hydrate, U.S.P.	S	
o-Chloronitrobenzene, tech.	S	
Dextrose	I	I (SS at 125°C)
Dianisidine, tech.	S	
p-Dichlorobenzene	S	
Diglycol stearate	SS	I (S at 100°C)
N,N-Dimethyl-para-nitrosoaniline	S	
Dinitrochlorobenzene, tech.	S	
Dinitronaphthalene	I	I (S at 120°C)
Dinitrophenol	S	
Diphenyl	S	
Diphenylamine	S	
Diphenylguanidine	S	
Hexamethylenetetramine, U.S.P.	S	
Iodoform, U.S.P.	I	I (S at 92°C)
Naphthalene	I	I (S at 92°C)
alpha-Naphthol, tech.	S	
beta-Naphthol, tech.	S	
beta-Naphthylamine, tech.	I	I (S at 92°C)
alpha-Naphthylamine hydrochloride	R (violent reaction)	
m-Nitroaniline	S	
p-Nitroaniline	S	
p-Nitrophenol, tech.	S	
p-Nitrotoluene	S	
m-Phenylenediamine	S	
Resorcinol, white, U.S.P.	S	
Saccharin, U.S.P.	I	I (SS at 125°C)
Sodium acetate	I	I (S at 115°C)
Sodium benzoate, U.S.P.	I	I (I at 125°C)
Sodium naphthionate, tech.	I	I (R at 112°C)
Sodium picramate, tech.	I	
Thiocarbanilide	I	I (S at 92°C)
2,4,6-Tribromophenol, tech.	S	
Triphenylguanidine, tech.	S	

S = Soluble SS = Slightly soluble I = Insoluble R = Reacts*

***Reactions of furfuryl alcohol in the presence of acid or acid generators may be violent; use caution.**

Table 6.159: Solubility of Thermoplastic Resins in Furfuryl Alcohol (at Room Temperature) *(46)*

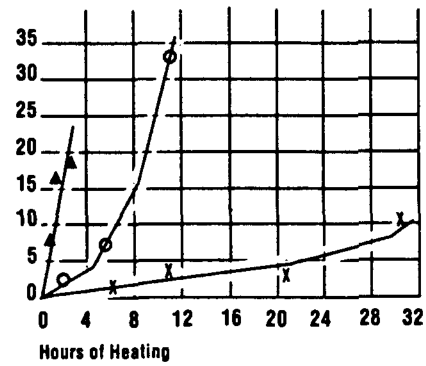
Resin Type	Tradename (Manufacturer)	Solubility
Cellulose acetate butyrate	CAB-500-1 (Tennessee Eastman)	VS
Cellulose nitrate	RS (Hercules)	VS
Ethylcellulose	N-50 (Hercules)	VS
Methyl methacrylate	Plexiglass® V(052)100 (Rohm & Haas)	S*
Methyl methacrylate	Plexiglass® VM100 (Rohm & Haas)	S*
Nylon	Elvamide® 8023 (DuPont)	VS
Nylon	Elvamide® 8061 (DuPont)	S*
Nylon	Elvamide® 8061M (DuPont)	VS*
Nylon	Elvamide® 8064 (DuPont)	S*
Nylon	Elvamide® 80625 (DuPont)	S
Nylon	Elvamide® PB8066 (DuPont)	S
Nylon	Rilsan® BMNO (Rilsan Corp.)	I
Polyethylene	Dowlex® 2045 (Dow Chemical)	I
Polyethylene	Dowlex® 2598TB (Dow Chemical)	I
Vinyl acetate	Bakelite® AYAT (Union Carbide)	VS
Vinyl acetate-chloride	Bakelite® VYHH (Union Carbide)	I
Vinyl butyral	Bakelite® XYHL (Union Carbide)	VS
Vinylidene chloride	Saran F-310 (Dow Chemical)	I

S = Soluble from 1 g to 10 g per 100 g solvent
VS = Soluble 10 g or more per 100 g solvent
I = Less than 1 g per 100 g solvent
* = Slowly

Table 6.160: Effect of Time at Elevated Temperature on Certain Characteristics of Furfuryl Alcohol (Under Neutral Conditions) *(46)*

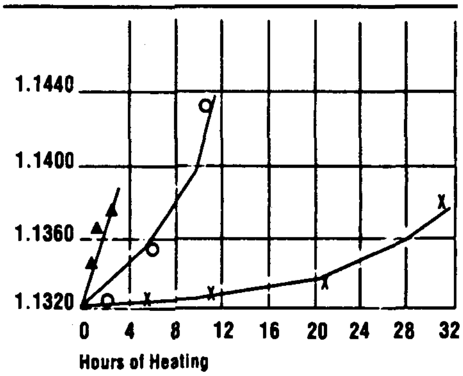
Rate of Water Formation

1 m H_2O/2 m Furfuryl Alcohol x 10^2



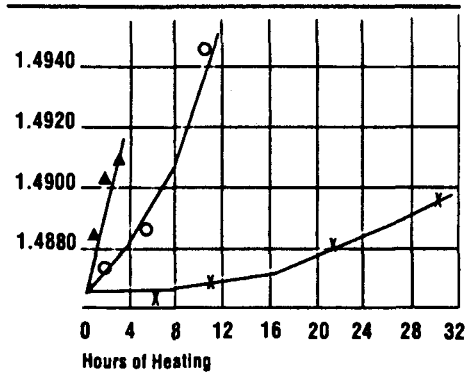
Rate of Change of Specific Gravity

Specific Gravity, d_{25}^{25}



Rate of Change of Refractive Index

Refractive Index, n_D^{20}



Legend:
x — At 100°C
○ — At 150°C
▲ — At 200°C

A.P. Dunlop and F.N. Peters, Jr., *Ind. & Eng. Chem.*, 34, 814 (1942).

Table 6.161: Stabilization of Furfuryl Alcohol With an Amine (at 150°C in Glass) *(46)*

Stabilization of Furfuryl Alcohol with an Amine (at 150°C in glass)

Stabilizer	Time, Hours	Refractive Index, n 20/D	Density, d 25/25	Cloud Point, °C	Water, %
None	0.0	1.4870	1.1322	5.5	0.03
	1.5	1.4875	1.1333	13.5	0.18
	5.5	1.4890	1.1356	36.0	0.67
	10.5	1.4944	1.1428	insol. @ 100°C	3.05
n-butyl amine, 0.3%	0.0	1.4868	1.1308	8.5	0.09
	1.5	1.4870	1.1309	8.5	0.06
	5.5	1.4869	1.1310	8.5	0.16
	10.5	1.4871	1.1311	9.0	0.19

A.P. Dunlop and F.N. Peters, Jr., *Ind. Eng. Chem.*, **34**, 814 (1942).

Table 6.162: Antoxidation of Furfuryl Alcohol *(46)*

Oxygen Absorption, Moles O_2/Liter Furfuryl Alcohol (Under Accelerated Laboratory Conditions)

Time, Hours	Furfuryl Alcohol	Furfuryl Alcohol plus 0.5% H_2O	Furfuryl Alcohol plus 0.5% Tripropylamine	Furfuryl Alcohol plus 0.5% Hydroquinone
42	0.075	0.139	—	—
74	0.250	0.377	—	—
127	0.636	0.672	—	—
162	0.840	0.852	—	—
215	0.972	—	—	—
264	1.084	—	—	0.074
330	1.229	—	0.019	0.117
Acidity, equiv/liter Furfuryl Alcohol				
0 (initial)	0.004	0.004	0.012	0.005
330 (final)	0.365	0.395	0.003	0.041

TETRAHYDROFURFURYL ALCOHOL *(46)*

Table 6.163: Physical Properties of Tetrahydrofurfuryl Alcohol *(46)*

Physical Properties of THFA®

Property	Value
Molecular weight	102.13
Appearance	colorless liquid
Boiling point at 760 mm, °C	178
Vapor pressure	see pg. 6
Freezing point, °C	below -80
Specific gravity at 20/20°C	1.054
Pounds per gal. at 20°C	8.79
Refractive index n_D^{20}	1.452
Surface tension at 25°C, dynes/cm	37
Viscosity at 20°C, cps absolute	6.24
Specific heat, liquid at 20°C, cal/g°C	0.424
Heat of vaporization, cal/g	120.6
Heat of combustion, kcal/mol at constant pressure	709.5
Flash point (Tag closed-cup), °C	74
°F	165
Auto-ignition temperature, °C	282
Flammability limits in air	
lower, vol %	1.5
upper, vol %	9.7
Dielectric constant at 23°C	13.6
Solubility parameter (est.)	12-13
Relative evaporation rate (n-butyl acetate=1.00)	.03

QO® THFA® Specifications

Specification	Value
THFA*, Assay, wt. % min.	98.0
Furfuryl alcohol, wt. % max.	0.1
1,2-Pentanediol, wt. % max.	1.6
Moisture, wt.% max.	0.3
Color, APHA, max.	50
Inhibitor	
Polygard, wt. %	0.025
Sodium borohydride, wt. %	0.005

Table 6.164: Solubility of Various Substances in Tetrahydrofurfuryl Alcohol *(46)*

	20 wt. % solute	10 wt. % solute
Acids:		
Acetylsalicylic	S	
Anthranilic	S	
Benzoic	S	
Butyric	S	
Citric	SS	S
Cresylic	S	
Lactic	SS (S at 120°)	
Naphthionic	SS	S
Oxalic	SS	S
Stearic	I	I (S at 100°)
Sulfanilic	I	I (I at 130°)
Tannic	I	I (SS at 130°)
Tartaric	SS	
Trichloroacetic	S	
Valeric	S	
Alcohols:		
Benzyl alcohol	S	
Chloral hydrate	S	
Dinitrophenol	S	
Ethanol	S	
Ethylene glycol	S	
Glycerol	S	
Isobutanol	S	
Isopropanol	S	
α–Naphthol	S	
β–Naphthol	S	
Pentanol	S	
Propanol	S	
Aldehydes:		
Benzaldehyde	S	
Crotonaldehyde	S	
Paraldehyde	S	
Amines:		
Aniline	S	
Benzidine	S	
Dianisidine	SS	S
Diethyl aniline	S	
Dimethyl aniline	S	
Diphenylamine	S	
Hexamethylenetetramine	I	I (SS at 130°)
β-Naphthylamine	SS	S
m-Phenylenediamine	S	
Pyridine	S	
o-Toluidine	S	
Triphenylguanidine	SS	S
Xylidine	S	
Aromatics:		
Anthracene	I	I (S at 100°)
Benzene	S	
Dinitronaphthalene	I	I (S at 120°)
Diphenyl	SS	S
Naphthalene	S	
p-Nitrophenol	S	
o-Nitrotoluene	S	
p-Nitrotoluene	I	S
Xylol	S	

	20 wt. % solute	10 wt. % solute
Esters:		
Amyl acetate	S	
Butyl acetate	S	
Cellulose acetate	S	
Diethyl acetate	S	
Diethyl phthalate	S	
Ethyl acetate	S	
Ethyl acetoacetate	S	
Methyl acetate	S	
Ethers:		
Dichloroethyl	S	
Diethlylene glycol monobutyl	S	
Diethlyene glycol monoethyl	S	
Ethyl	S	
Ethylene glycol monobutyl	S	
Ethylene glycol monoethyl	S	
Halides:		
Benzyl chloride	S	
Bromobenzene	S	
Bromoform	S	
Chloroform	S	
o-Dichlorobenzene	S	
p-Dichlorobenzene	SS	S
Dinitrochlorobenzene	SS	S
Ethyl bromide	S	
Ethylene chloride	S	
Iodoform	S	
o-Nitrochlorobenzene	SS	S
Tetrachloroethane	S	
Ketones:		
Acetone	S	
Anthraquinone	I	I (I at 130°)
Methyl ethyl ketone	S	
Oils:		
Aniline	S	
Castor	I	
Chinawood	I	
Coconut	I	
Cottonseed	I	
Lard	I (S at 120°)	
Linseed	I (S at 120°)	
Menhaden	I (S at 120°)	
Neat's-foot	I (S at 120°)	
Peanut	I (S at 120°)	
Rape-seed	I (S at 120°)	
Sperm	I (S at 120°)	
Turkey Red	S	
Whale	I (S at 120°)	
Miscellaneous Compounds:		
Caffeine	I	
Camphor, monobromo	I	
Casein	I	
Chloramine	I	I (SS at 130°)
Dextrose	I	I (S at 100°)
Sodium acetate	SS	S
Sodium benzoate	I	SS (SS at 135°)

Key: S=Soluble; I=Insoluble; SS=Slightly Soluble; temp= Fahrenheit

Table 6.165: Vapor-Liquid Equilibria in the Tetrahydrofurfuryl Alcohol-Water System *(46)*

Liquid Phase			Vapor Phase			Boiling Point	
	Mole Fraction			Mole Fraction			
Weight %	THFA	Water	Weight %	THFA	Water	Temperature °C	Pressure mm HG
1.0	0.0018	0.9982	—	—	—	100.0	749.5
2.6	0.0048	0.9952	1.0	0.0018	0.9982	100.4	749.5
5.7	0.0106	0.9894	2.0	0.0036	0.9964	100.5	747.8
6.1	0.0113	0.9887	2.3	0.0041	0.9959	100.6	747.8
9.7	0.0166	0.9814	3.4	0.0062	0.9938	100.6	749.5
13.5	0.0267	0.9733	4.3	0.0079	0.9921	101.0	749.2
17.2	0.0354	0.9646	4.9	0.0090	0.9910	101.0	747.8
20.3	0.0430	0.9570	5.7	0.0106	0.9894	101.0	749.0
24.6	0.0544	0.9456	6.2	0.0115	0.9885	101.0	747.8
30.2	0.0709	0.9291	7.2	0.0135	0.9865	102.0	749.5
30.8	0.0728	0.9272	7.3	0.0137	0.9863	101.0	749.0
36.9	0.0936	0.9064	8.0	0.0151	0.9849	101.0	748.9
44.8	0.125	0.875	9.6	0.0185	0.9815	102.0	752.5
44.9	0.126	0.874	9.7	0.0186	0.9814	102.0	753.7
49.3	0.146	0.854	10.5	0.0202	0.9798	102.1	755.9
53.4	0.168	0.832	11.3	0.0220	0.9780	102.5	754.1
58.9	0.202	0.798	11.8	0.0231	0.9769	103.0	754.6
63.6	0.234	0.766	13.3	0.0262	0.9738	103.0	754.9
70.4	0.296	0.704	14.5	0.0290	0.9710	104.0	755.2
77.3	0.375	0.625	18.5	0.0384	0.9816	105.5	755.2
79.3	0.403	0.597	18.5	0.0384	0.9616	106.0	747.8
81.1	0.431	0.569	18.9	0.0394	0.9606	106.0	748.4
82.3	0.451	0.549	20.4	0.0432	0.9568	107.0	741.1
84.9	0.496	0.504	20.3	0.0430	0.9570	107.0	748.4
86.1	0.522	0.478	24.7	0.0547	0.9453	108.0	745.9
87.1	0.546	0.454	27.4	0.0625	0.9375	107.0	741.9
92.6	0.688	0.312	40.1	0.106	0.894	119.0	745.6
95.4	0.785	0.215	65.3	0.249	0.751	139.5	745.8
98.0	0.896	0.104	87.5	0.553	0.447	148.0	750.9

Table 6.166: Specific Gravity and Pounds per Gallon of Tetrahydrofurfuryl Alcohol at Various Temperatures *(46)*

°C	°F	Specific Gravity	Density (lb/gal)
50	122.0	1.026	8.566
48	118.4	1.028	8.581
46	114.8	1.030	8.596
44	111.2	1.032	8.610
42	107.6	1.034	8.626
40	104.0	1.035	8.641
38	100.4	1.037	8.656
36	96.8	1.039	8.671
34	93.2	1.041	8.686
32	89.6	1.043	8.701
30	86.0	1.044	8.716
28	82.4	1.046	8.731
26	78.8	1.048	8.746
24	75.2	1.049	8.761
22	71.6	1.052	8.776
20	68.0	1.053	8.791
18	64.4	1.055	8.806
16	60.8	1.057	8.821
14	57.2	1.059	8.836
12	53.6	1.061	8.851
10	50.0	1.062	8.866
8	46.4	1.064	8.881
6	42.8	1.066	8.896
4	39.2	1.068	8.911
2	35.6	1.070	8.926
0	32.0	1.071	8.931

Change per °C : Sp. Gr. −0.0009
Lbs./Gal. −0.00751

Table 6.167: Vapor Pressure of Tetrahydrofurfuryl Alcohol *(46)*

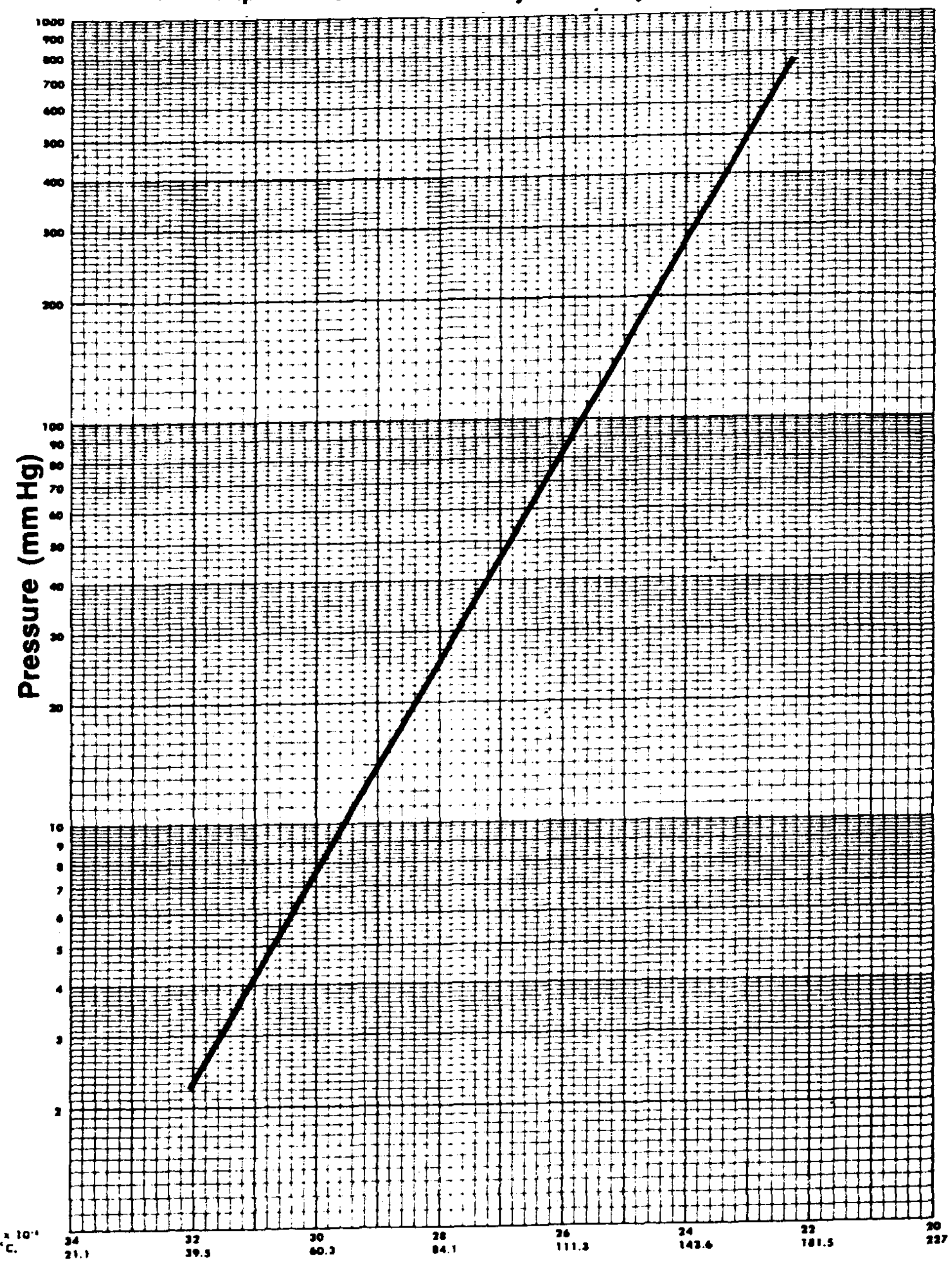


Table 6.168: Vapor-Liquid Equilibria Curve of the THFA-Water System at the Boiling Point *(46)*

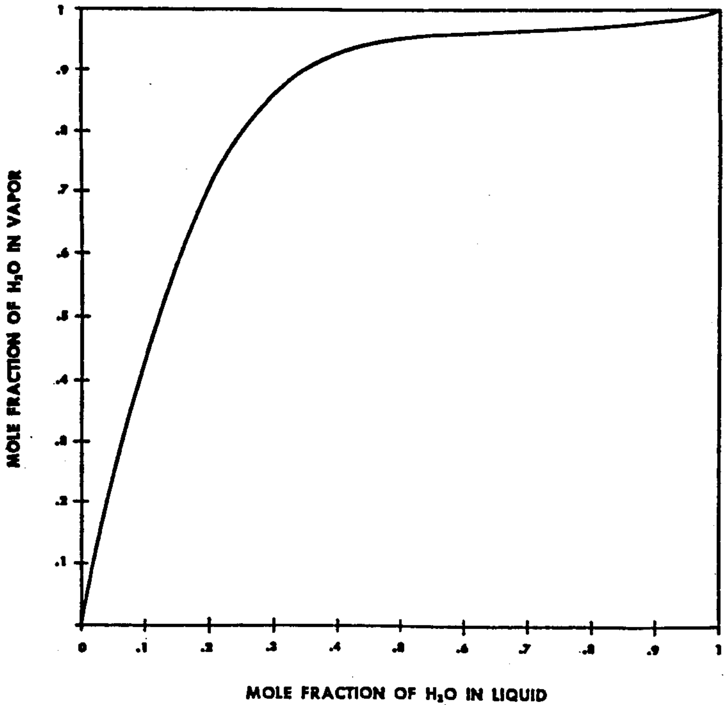


Table 6.169: The System THFA-Water Composition Curve *(46)*

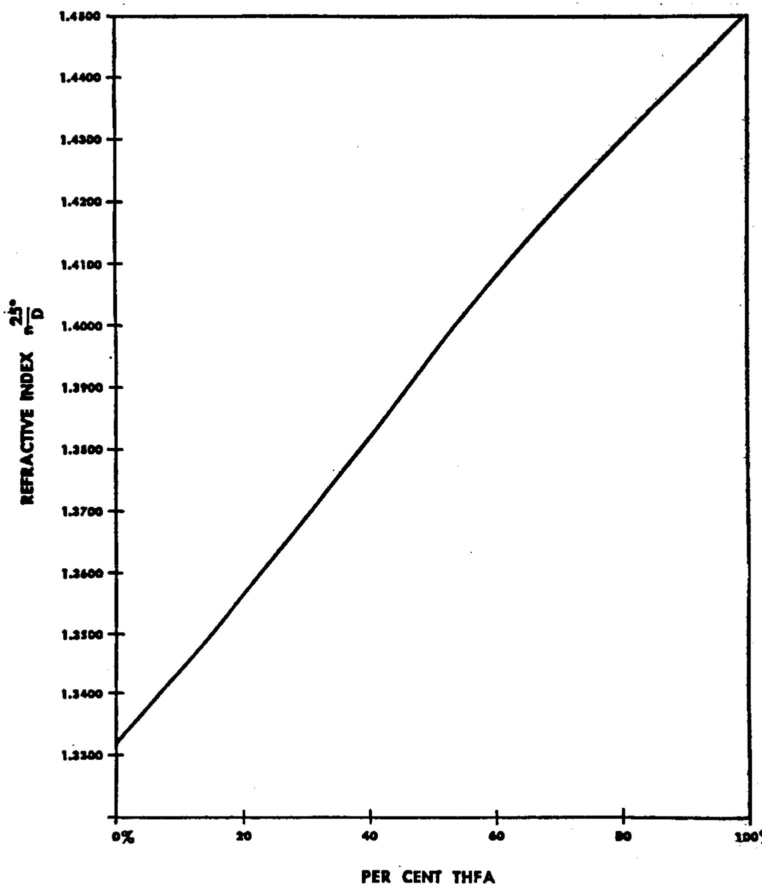


Table 6.170: Specific Gravity and Pounds per Gallon *(46)*

Temperature °C	°F	Sp. Gr.*	Lbs./Gal.
50	122.0	1.031	8.588
40	104.0	1.039	8.656
30	86.0	1.047	8.724
20	68.0	1.055	8.792
10	50.0	1.064	8.859
0	32.0	1.072	8.927

Change per °C: Sp. Gr.—0.000815 Lbs./Gal.—0.00679
*Referred to water at 20°C

Table 6.171: Vapor Pressure (Boiling Point Method) *(46)*

Pressure (mm)	°C	°K	1/°K
2.3	41.6	314.6	0.00318
5.2	53.6	326.6	0.00306
45.5	96.5	369.5	0.00271
73.3	108.5	381.5	0.00262
83.3	111.3	384.3	0.00260
120.0	120.5	393.5	0.00254
196.0	137.5	410.5	0.00244
303.0	146.0	419.0	0.00239
400.0	155.0	428.0	0.00234
495.9	162.5	435.5	0.00230
598.0	168.2	441.2	0.00227
747.0	177.8	450.8	0.00222

Table 6.172: HERCO and YARMOR Pine Oil *(28)*

HERCO® PINE OIL

A High-Quality, General-Purpose-Grade Pine Oil

HERCO® pine oil[a] is a clear, pale yellow to near-water-white, oily liquid with a distinct pinelike odor. Derived from terpene oils of pinewood origin, it is a blend of related compounds, largely terpene alcohols. Herco pine oil meets requirements of Federal Specification LLL-P-400a for Type 1 pine oil. It is especially indicated for manufacture of high-performance cleaners and disinfectants, and for all other uses where a pine oil of uniform, high-terpene-alcohol content is required.

(a) Herco pine oil is registered with the Office of Pesticide Program of the U.S. Environmental Protection Agency under EPA Registration Number 891-175.

General Sales Specifications

Hercules Test Methods are available on request

Specific gravity at 15.6/15.6°C	0.930-0.938
Total terpene alcohols, % min	80
Moisture, % max	0.5
Color, APHA, max	70

Typical Properties

Specific gravity at 15.6/15.6°C	0.933
Total terpene alcohols, %	85
Moisture, %	0.4
Distillation range, °C, (5% to 95%)	206 - 220
Refractive index at 20°C	1.481
Color, APHA	25
Kauri-butanol value	>500
Flashpoint, TCC °F (°C)	150 (66)
Density at 60°F (15.6°C), lbs/gal (kg,l)	7.78 (.93)
Freezing point, °F (°C)	39 (4)

Outstanding Characteristics

Clear, pale color; high terpene alcohol content; piney odor; high solvent activity; excellent wetting, penetrating, and dispersing properties, high bactericidal activity when properly formulated; uniform

(continued)

Table 6.172: (continued)

YARMOR® F PINE OIL

Flotation-Grade Pine Oil

YARMOR® F pine oil is a frothing agent designed for flotation processes, particularly for benefication of metallic sulfide ores. Derived chiefly from oils extracted from pinewood, it is a mixture of terpenes, predominantly alcohols with lesser amounts of related terpenes.

Yarmor F produces a strong froth of good volume, satisfactory texture, and excellent cell life stability. Although normally used as a frother, it is also an effective collector for certain minerals.

General Sales Specifications
Hercules Test Methods are available on request

Specific gravity at 15.6/15.6 °C	0.930-0.950
Total alcohols, % min	70
Moisture, % max	1.8

Typical Properties

Specific gravity at 15.6/15.6 °C	0.938
Total alcohols, %	75
Moisture, %	1.1
Refractive index at 20 °C	1.484
Color, Gardner	3
Distillation range, °C	
5%	205
95%	227
Flashpoint, COC, °F(°C)	169(76)
Weight/gal, lbs (kg/l), 60 °F (15.6 °C)	7.8(.94)
Viscosity, Ubbelohde, at 77 °F (25 °C), cps	10
Freezing point,[a] °F (°C)	32(0)

(a)Yarmor F will supecool and can be handled satisfactorily at lower temperatures

Outstanding Characteristics
Strong froth; excellent cell life stability; excellent wetting properties; low freezing point; low volatility

YARMOR® 60 PINE OIL

Terpene Alcohol

YARMOR® 60 pine oil[a] is a clear, pale yellow to near water-white oily liquid with a distinct pinelike odor. Derived from terpene oils of pinewood origin, it is a blend of related compounds, principally terpene alcohols. It is intended for manufacture of cleaners and disinfectants, and for other uses where a good-quality pine oil is required.

(a)Yarmor 60 pine oil is registered with the Office of Pesticide Programs of the U. S. Environmental Protection Agency under EPA Registration Number 891-181.

General Sales Specifications
Hercules Test Methods are available on request

Specific gravity at 15.6/15.6 °C	0.909-0.919
Total terpene alcohols, % min	60
Moisture, % max	0.5
Color APHA, max	70

Typical Properties

Total terpene alcohols, %	62.7
Moisture, %	0.3
Distillation range, °C	
5%	196.6
95%	224.9
Color, Hazen	20
Color, (Hercules terpene)	0.2
Kauri-butanol value	500
Flashpoint, TOC, °C (°F)	60(140)
Weight, lbs/gal (kg/l), 60 °F, (15.6 °C)	7.75(.91)
Specific gravity at 15.6/15.6 °C	0.91

Outstanding Characteristics
Clear, pale color; high terpene alcohol content; piney odor; high solvent activity; excellent wetting, penetrating, and dispersing properties

(continued)

Table 6.172: (continued)

YARMOR® 302 PINE OIL

Highest Quality, All Purpose-Grade Pine Oil

YARMOR® 302 pine oil[a] is a clear, pale yellow to near-water-white, oily liquid with a distinct pinelike odor. Derived from terpene oils of pinewood origin, it is a blend of related compounds, mainly terpene alcohols. Yarmor 302 meets requirements of Federal Specification LLL-P-400a for Type 1 pine oil.

(a)Yarmor 302 pine oil is registered with the Office of Pesticide Programs of the U.S. Environmental Protection Agency under EPA Registration Number 891-174

General Sales Specifications

Hercules Test Methods are available on request

Specific gravity at 15.6/15.6 °C	0.938-0.946
Total terpene alcohols, % min	85
Moisture, % max	0.5
Color, APHA, max	70

Typical Properties

Specific gravity at 15.6/15.6 °C	0.941
Secondary alcohols, %	16
Tertiary alcohols, %	76
Total terpene alcohols, %	92
Moisture, %	0.35
Refractive index at 20 °C	1.481
Color, APHA	25
Kauri-butanol value	>500
Flashpoint, TCC, °F (°C)	172(78)
Freezing Point, °F (°C)	41 (5)
Weight/gal, lbs (kg/l), 60°F (15.6°C)	7.85 (0.94)

Outstanding Characteristics

Clear, pale color; high terpene alcohol content; piney odor; high solvent activity; excellent wetting, penetrating, and dispersing properties; high bactericidal activity when properly formulated.

YARMOR® 302W PINE OIL

A General-Purpose-Grade Pine Oil

YARMOR® 302W pine oil[a] is a clear, pale yellow to near-white-water, oily liquid with a distinct pinelike odor. Derived from terpene oils of pinewood origin, it is a blend of related compounds, predominantly terpene alcohols with minor amounts of terpene hydrocarbons. It is suitable for all uses where a general-purpose grade of pine oil is required.

(a)Yarmor 302W pine oil is registered with the Office of Pesticide Programs of the U.S. Environmental Protection Agency under EPA Registration Number 891-176

General Sales Specifications

Hercules Test Methods are available on request

Specific gravity at 15.6/15.6 °C	0.920-0.930
Total alcohols, % min	70
Moisture, % max	0.5
Color, APHA, max	70

Typical Properties

Specific gravity at 15.6/15.6 °C	0.923
Secondary alcohols, %	8
Tertiary alcohols, %	65
Total terpene alcohols, %	73
Monocyclic terpenes, %	27
Moisture, %	0.35
Refractive index at 20 °C	1.480
Color, APHA	25
Kauri-butanol value	>500
Flashpoint, TCC, °F(°C)	130(54)
Weight/gal, lbs (kg/l), 60 °F (15.6 °C)	7.67(.92)

Outstanding Characteristics

Clear, pale color; piney odor; high solvent activity; excellent wetting, penetrating, and dispersing properties; high bactericidal activity when properly formulated; uniform.

(continued)

Table 6.173: Hercules TERPINEOL *(28)*

TERPINEOL™ 101

Natural Tertiary Terpene Alcohol

TERPINEOL™ 101 is a natural, high-purity grade of the tertiary terpene alcohol *alpha*-terpineol. Derived by fractional distillation of oils extracted from pinewood, it is a water-white, oily liquid at normal temperatures with an odor suggestive of lilacs. Its chemical nature, pleasant floral odor, and surface-active properties account for its usefulness to the essential-oil industry and to manufacturers of disinfectants, household and industrial soaps, detergents, cleaners, and other chemical specialties.

General Sales Specifications

Hercules Test Methods are available on request

Specific gravity at 15.6/15.6°C, min	0.935
Tertiary alcohols, min, %	94
Moisture, max, %	0.6
Color, Hazen (APHA), max	70
Appearance	EFFM[a]

(a) Essesentially Free of Foreign Matter

Typical Properties

Specific gravity at 15.6/15.6°C	0.9410
Tertiary alcohols, %	96
Moisture, %	0.2
Distillation range, °C (°F)	
5%	219 (426)
95%	220 (428)
Color, Hazen (APHA)	20
Flashpoint, COC, °C (°F)	90 (194)
Freezing point, °C (°F)	<25 (<77)
Weight/gal, lbs (kg/l)	7.85 (0.94)

Outstanding Characteristics

High purity; natural origin; light color; pleasant floral odor; strong masking agent; excellent solvent; promotes surface activity; antibacterial activity when properly formulated.

TERPINEOL™ 200

Synthetic Tertiary Terpene Alcohol

TERPINEOL™ 200 is a high-purity grade of the tertiary terpene alcohol *alpha*-terpineol. Derived synthetically by hydrating *alpha*-pinene, it is a water-white, oily liquid at normal temperatures. Its chemical nature, pleasant floral odor, and surface-active properties account for its usefulness to the essential-oil industry and to manufacturers of disinfectants, household and industrial soaps, detergents, cleaners, and other chemical specialties.

General Sales Specifications

Hercules Test Methods are available on request

Specific gravity at 15.6/15.6°C, min	0.935
Tertiary alcohols, %, min	95
alpha/gamma-Terpineol, %, min	93.5
Moisture, max, %	0.6
Color, Hazen (APHA), max	70

Typical Properties

Specific gravity at 15.6/15.6°C	0.941
Tertiary alcohols, %	97
Moisture, %	0.2
alpha/gamma-Terpineol, %	96.2
Distillation range, °C (°F)	
5%	217 (422)
95%	220 (428)
Color, Hazen (APHA)	20
Flashpoint, COC, °C (°F)	88 (190)
Freezing point, °C (°F)	<25 (<77)
Weight/gal, lbs (kg/l)	7.85 (0.94)

Outstanding Characteristics

High purity; light color; pleasant floral odor; strong masking agent; excellent solvent; promotes surface activity; antibacterial activity when properly formulated.

(continued)

Table 6.173: (continued)

TERPINEOL™ 318 PRIME

Mixed Tertiary Terpene Alcohols

TERPINEOL™ 318 Prime is a mixture of isomeric terpineols obtained by dehydration of terpine hydrate. It is composed predominantly of *alpha*-terpineol, with lesser amounts of beta and gamma-terpineols. At normal temperatures, Terpineol 318 Prime is a water-white, oily liquid with a hyacinth-like odor. Terpineol 318 Prime is used by chemical specialties manufacturers for its odor, and by the essential-oils industry to produce perfume ingredients, particularly for soaps.

General Sales Specifications

Hercules Test Methods are available on request

Color, Hazen (APHA), max	70
Specific gravity, at 15.6/15.6°C, min	0.935
Moisture, max %	0.6
beta/delta-Terpineol, %	8 to 20
alpha/gamma-Terpineol, %	80 to 90
Tertiary alcohols, min, %	98

Typical Properties

Color, Hazen (APHA)	30
Specific gravity at 15.6/15.6°C	0.938
Moisture, %	0.2
Freezing point, °C (°F)	<-10 (+14)
Flashpoint, COC, °C (°F)	88 (190)
Weight/gal, lbs (kg/l)	7.8 (0.94)

Outstanding Characteristics

High purity; light color; pleasant floral odor; excellent solvent; promotes surface activity; resistant to alkalies.

Table 6.174: Solubility Data for Alcohols *(57)*

	Cellulose Acetate (LL-1)	Cellulose Acetate Butyrate		Cellulose Acetate Propionate		Ethyl Cellulose	Polystyrene	Methyl Methacrylate	Bakelite* Vinyl .... Resins			Hydrocarbons	Linseed Oil (Raw)	Rosin	Ester Gum	Shellac	Unvulcanized Rubber	Relative Evap. Rate (n-Butyl Acetate = 100)	Density (lb gal) at 20°C
		17% Butyryl	37% Butyryl	13-15% Propionyl	31% Propionyl				VYHH	AYAF	XYHL								
Methanol	I	I	I	I	I	S	I	I	I	S	S	PS	SS	PS	I	S	I	610	6.60
Ethanol	I	I	I	I	I	S	I	I	I	S	S	S	SS	S	I	S	I	340	6.76
Isopropanol	I	I	I	I	I	PS**	I	I	I	SS	S**	S	SS	S	I	S	I	300	6.55
n-Propanol	I	I	I	I	I	S	I	I	I	SS	S**	S	S	S	I	S	I	—	—
n-Butyl alcohol	I	I	I	I	I	S	I	I	I	SS	S**	S	S	S	S	S	I	45	6.75
Isobutanol	I	I	I	I	I	S	I	I	I	SS	S**	S	S	S	PS	S	I	80	6.68
Mixed amyl alcohols	I	I	I	I	I	S	I	I	I	I	S**	S	S	S	S	S	I	—	—
3-Methoxy butanol	I	I	S	I	I	S	I	I	I	S	S	S	S	S	S	S	I	12	7.68
Pentanol-3	I	I	I	I	I	S	I	I	I	SS	S	S	S	S	S	S	I	54	6.84
Methyl amyl alcohol	I	I	I	I	I	S**	I	I	I	SW	S**	S	S	S	S	SS	I	33	6.72
2-Ethylbutanol	I	I	I	I	I	S**	I	I	I	SW	S**	S	S	S	S	S	I	8	6.92
n-Hexanol	I	I	I	I	I	S**	I	I	I	I	S**	S	S	S	S	S	I	5	6.83
Heptanol-3	I	I	I	I	I	S**	I	I	I	SW	S**	S	S	S	S	SS	I	6	6.84
2-Ethylhexanol	I	I	I	I	I	S**	I	I	I	I	S**	S	S	S	S	S	I	<1	6.94
Diisobutyl carbinol	I	I	I	I	I	PS**	I	I	I	I	SW	S	S	S	S	I	I	2	6.75
Trimethyl nonyl alcohol	I	I	I	I	I	PS**	I	I	I	I	SW	S	S	S	S	I	I	<1	6.83
Undecanol	I	I	I	I	I	S**	I	I	I	SW	G	S	S	S	S	PS	PS	<1	6.97
Tetradecanol	I	I	I	I	I	SS**	I	I	I	I	I	S	S	S	S	I	PS	<1	6.95
Heptadecanol	I	I	I	I	I	I	I	I	I	I	I	S	S	S	S	I	PS	<1	7.05
Trimethyl cyclohexanol	I	I	SS	I	I	S	I	I	I	I	S-G	S	S	S	S	I	SW	<1	8.21***
Tetrahydropyran-2-methanol	I	I	S	I	S	S	S	I	S	S	S	S	S	S	S	S	I	3	—
2-Mercaptoethanol	S	S**	S	S	S	S	SS	S	SS	S	S	PS†	Imm	S	S	S	I	13	9.30
Phenyl methyl carbinol	SW	SW	S	SW	S	S	S	SS	I	S	S	S	S	S	S	S	I	<1	8.45
Diacetone alcohol	S	PS	S	S	S	S	I	S	S	S	S	S	S	S	S	PS	I	14	7.82

*UCC trademark. **0.5 g resin to 9.5 ml solvent. ***At 55°C. †Miscible with toluene and xylene, immiscible with Apcothinner.

Legend:

S	Soluble	G	Gel
PS	Partly soluble	I	Insoluble
SS	Slightly soluble	SW	Swelling
S-G	Soluble, tendency to gel	Imm	Immiscible

Table 6.175: Melting Points of Saturated Monohydric Alcohols *(69)*

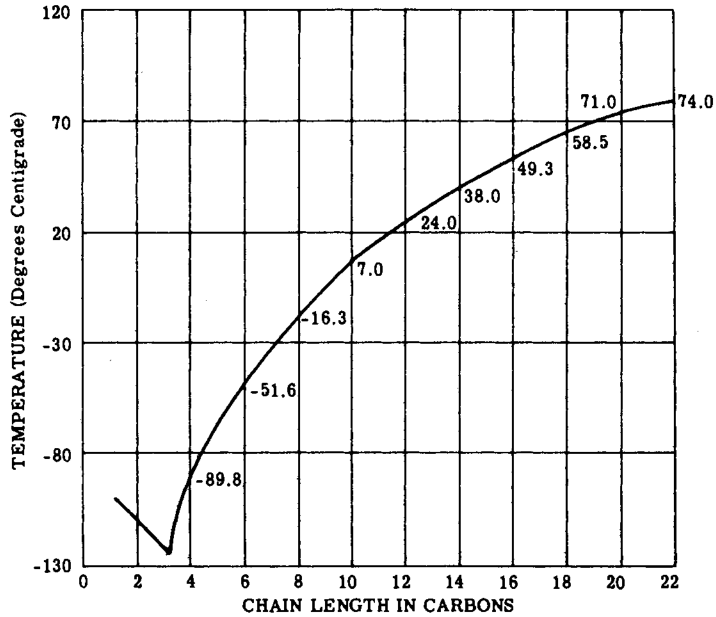


Table 6.176: Rate of Evaporation of Various Solvents at Room Temperature *(19)*

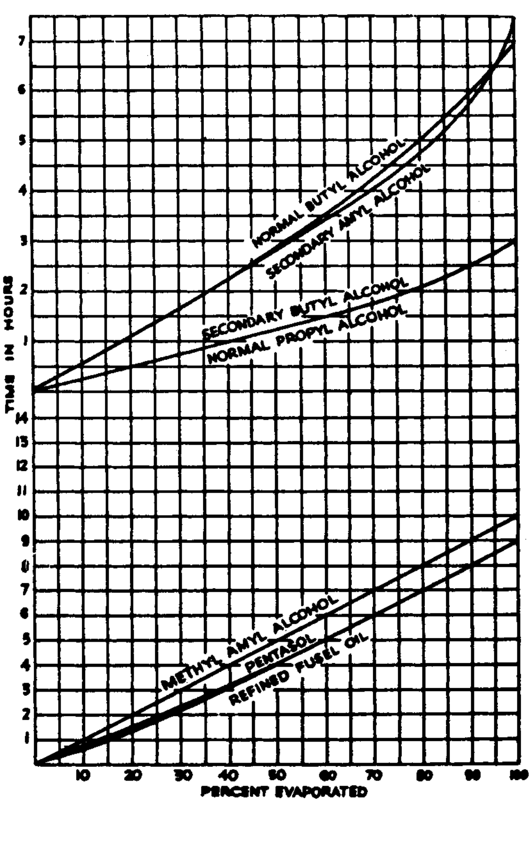


Table 6.177: Comparative Evaporation Rates of Alcohols *(19)*

(Relative Values on 5 cc Samples at 21°C. and 734.4 mm. Hg)

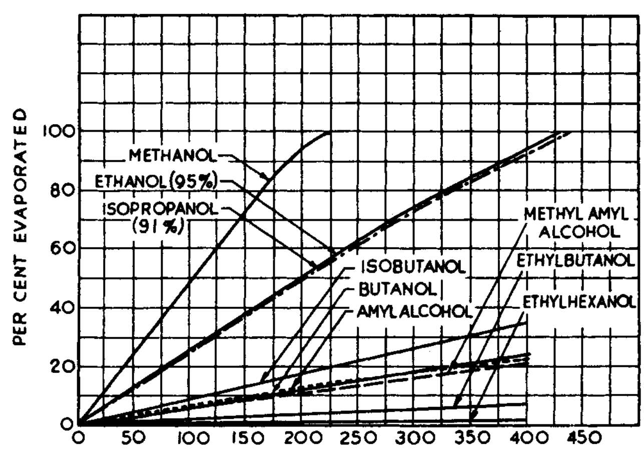


Table 6.178: Vapor Pressure of Alcohols at Various Temperatures *(19)*

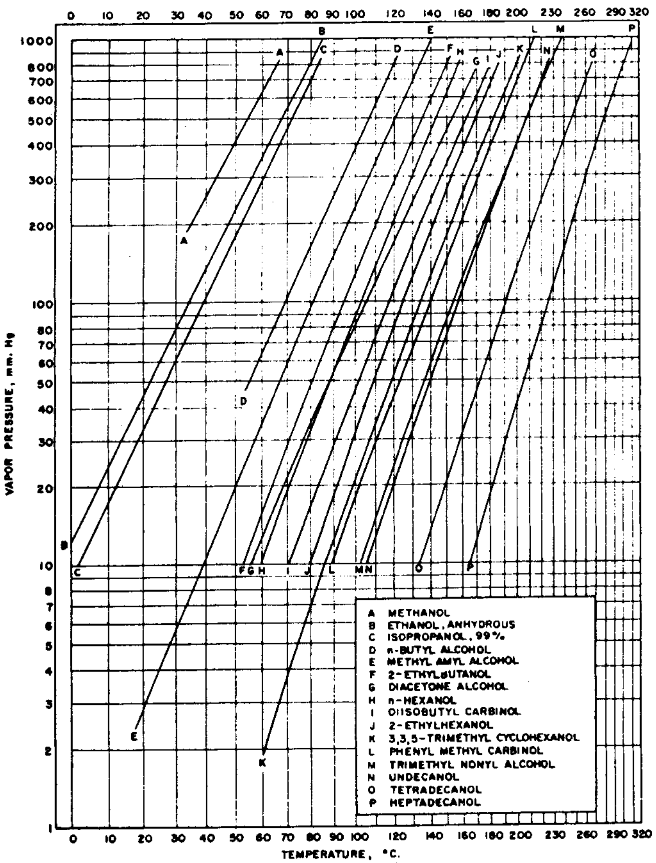


Table 6.179: Freezing Points (Initial Crystallization) of Aqueous Solution of Alcohols *(19)*

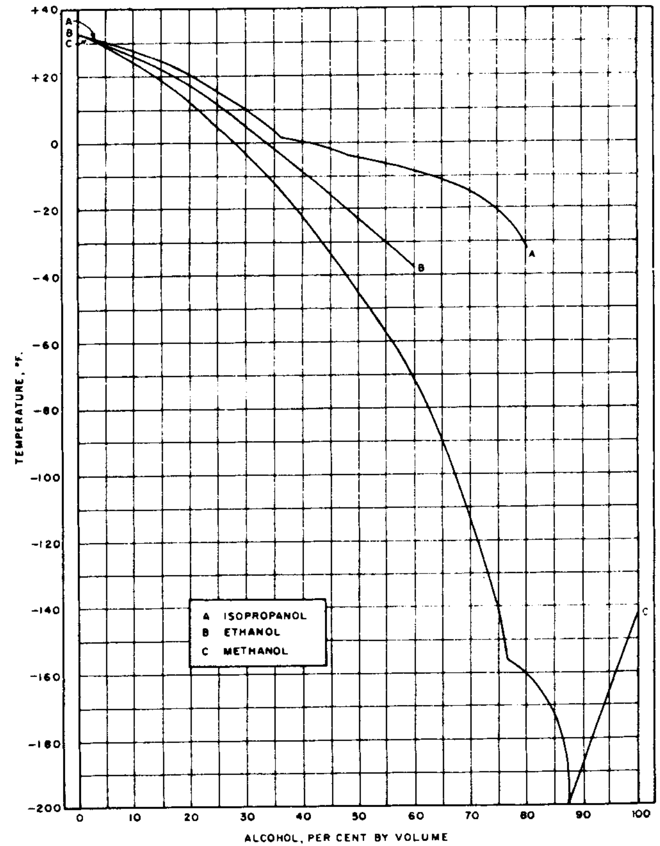


Table 6.180: Specific Gravity of Aqueous Solution of Alcohols at 20°C *(19)*

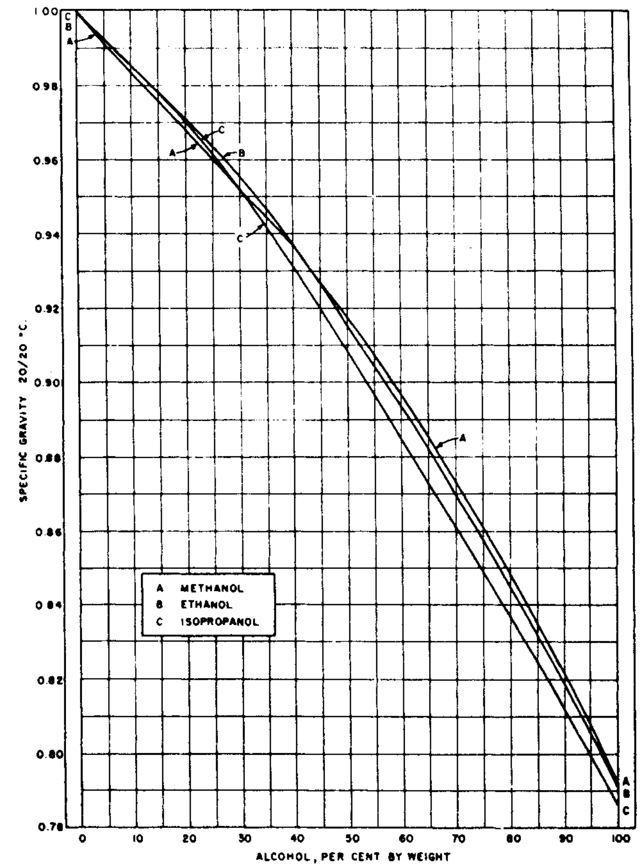


Table 6.181: Viscosity of Ethyl Cellulose in Alcohol-Hydrocarbon Mixtures *(14)*

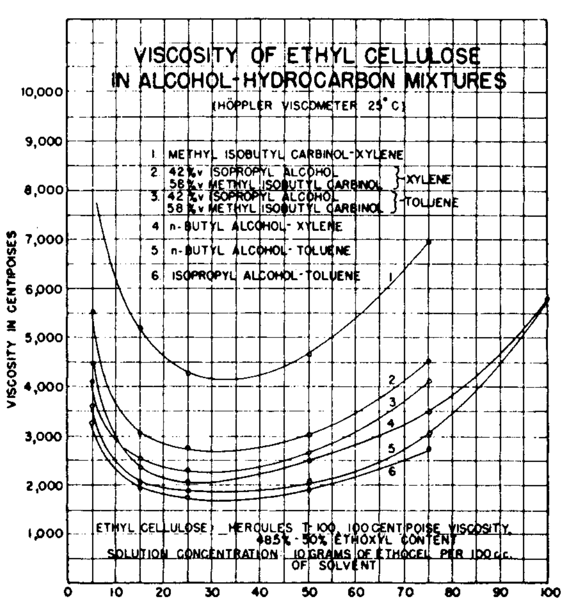


Table 6.182: Evaporation Data for Various Solvents *(14)*

Active Solvents	Rate of Evaporation (Normal Butyl Acetate–1.00)
Acetone	7.7
Methyl Ethyl Ketone	4.6
Ethyl Acetate (85-90%)	4.6
Isopropyl Acetate 95%	3.9
Secondary Butyl Acetate	1.8
Methyl Isobutyl Ketone	1.6
Methyl Isobutyl Ketone (82.5% w)– Methyl Isobutyl Carbinol (17.5% w)	1.0
Normal Butyl Acetate	1.0
Mesityl Oxide	0.9
Secondary Amyl Acetate	0.8
Amyl Acetate (mixed isomers)	0.6
Methyl Amyl Acetate	0.5
CELLOSOLVE Acetate	0.2
Diacetone Alcohol	0.2
Butyl CELLOSOLVE	0.1
Latent Solvents	
Ethyl Alcohol (anhydrous)	1.9
Isopropyl Alcohol (anhydrous)	1.7
Ethyl* Alcohol (190 proof)	1.7
Normal Butyl Alcohol (50% v)– Anhydrous Ethyl* Alcohol (50% v)	0.7
Methyl Isobutyl Carbinol (30% v)– Anhydrous Ethyl* Alcohol (70% v)	0.7
Methyl Isobutyl Carbinol (30% v)– Anhydrous Isopropyl Alcohol (70% v)	0.7
Normal Propyl Alcohol	1.1
Secondary Butyl Alcohol	1.0
Normal Butyl Alcohol	0.5
Methyl Isobutyl Carbinol (60% v)– Anhydrous Isopropyl Alcohol (40% v)	0.5
Secondary Amyl Alcohol	0.5
Amyl Alcohol (mixed isomers)	0.3
Methyl Isobutyl Carbinol	0.3

*Proprietary grade.

Diluents	
Toluene	2.1
Xylene	0.8

Polyhydric Alcohols

ETHYLENE GLYCOL

Glycol
1,2-Ethanediol

$HOCH_2CH_2OH$

Table 7.1: Physical Properties and Specifications of Ethylene Glycol *(32)*

Property	Value
Acidity as acetic acid	0.01% by wt., max.
Ash	0.005 g./100 ml., max.
Boiling point at 760 mm. Hg	197.2-197.6° C
Coefficient of expansion at 20° C	0.00062/°C 0.0006375/°C
Color, APHA	10-15 max.
Density (true) at 20° C	1.1134 g./ml.
Dielectric constant, 20° C	38.66 esu
Distillation at 760 mm. Hg Ibp 5 ml. 95 ml. Dp	193° C, min. 194° C, min. 200° C, min. 205-208° C
Electric conductivity at 25° C	1.07×10^{6} recip. ohms (mhos) cm.
Molecular weight	62.07
Odor	Mild
Pour point	-75° F
Refractive index n_D 25° C n_D 20° C	1.4306 1.4316
Specific gravity (apparent), 25/25° C 20/20° C	1.1133 1.1155
Specific heat at 20° C at 0° C	0.561 0.544
Spontaneous ignition temperature	398.9° C 412.8° C
Sulfates	Not detectable
Surface tension at 20° C	48.4 dynes/cm.
Suspended matter	Substantially free
Vapor at 20° C (68° F) 25° C (77° F) 93° C (200° F) 132.2° C (270° F)	0.06 mm. Hg 0.12 mm. Hg 11.0 mm. Hg 75.0 mm. Hg
Fire point, Cleveland, tag ASTM, open cup	250° F 245° F
Flash point (open cup) ASTM, open cup	245° F 240° F
Free energy of formation at 25° C	-80.2 kcal./mole
Heat of combustion (const. pressure) at 20° C	-283.3 kcal./mole
Heat of dilution $[C_2H_4(OH)_2 \times 2\ H_2O]$	0.06 cal./g.
Heat of formation at 20° C	-108.1 kcal./mole
Heat of fusion	44.7 cal./g.
Heat of vaporization at 760 mm. Hg	191 cal./g. 344 Btu/lb.
Inorganic chlorides, as Cl	0.1 ppm, max.
Iron	0.15 ppm, max.
Viscosity at 10° C (50° F) 25° C (77° F) 35° C (95° F) 60° C (140° F)	33.6 cp. 17.4 cp. 12.3 cp. 5.2 cp.
Water content	0.3% by wt., max.
Weight per gallon at 20° C	9.28 lb.

Ethylene Glycol

Glycol % by Wt.	% by Vol.	Flash Point °F Cleveland, Tag	Fire Point °F Cleveland
100	100	245	250
95	94.7	260	270
90	89.4	270	280

Table 7.2: Boiling Points of Aqueous Ethylene Glycol Solutions *(32)*

Glycol, % by Wt.	% by Vol.	Boiling Point °F	Glycol, % by Wt.	% by Vol.	Boiling Point °F	Glycol, % by Wt.	% by Vol.	Boiling Point °F
0	0.0	212	70	68.4	238	90	89.4	279
10	9.1	214	72	70.5	240	91	90.5	284
20	18.4	216	74	72.6	243	92	91.5	289
25	23.2	217	76	74.7	245	93	92.6	294
30	28.0	218	78	76.8	248	94	93.6	301
35	32.8	219	80	78.9	252	95	94.7	309
40	37.8	221	81	79.9	254	96	95.8	319
45	42.8	223	82	81.0	256	97	96.8	330
50	47.8	225	83	82.0	258	98	97.9	345
55	52.9	227	84	83.1	260	99	98.9	363
60	58.0	230	85	84.1	262	100	100	388
62	60.1	232	86	85.2	265			
64	62.2	233	87	86.2	268			
66	64.2	235	88	87.3	271			
68	66.3	236	89	88.4	275			

Table 7.3: Density of Aqueous Ethylene Glycol Solutions *(32)*

	Ethylene Glycol Percentage										
By Wt.	0	10	20	30	40	50	60	70	80	90	100
By Vol.	0	9.1	18.4	28.0	37.8	47.8	58.0	68.4	78.9	89.4	100
Temp. °F	Density in g./ml.										
-50							1.110	1.125	1.137		
-40							1.108	1.122	1.134		
-30						1.087	1.105	1.120	1.131		
-20						1.086	1.103	1.117	1.128	1.138	
-10					1.068	1.084	1.100	1.114	1.125	1.135	
0					1.066	1.082	1.097	1.111	1.122	1.131	
10				1.048	1.064	1.080	1.095	1.107	1.118	1.128	1.136
20			1.031	1.147	1.063	1.077	1.092	1.104	1.115	1.124	1.132
30		1.015	1.030	1.045	1.061	1.075	1.089	1.101	1.111	1.121	1.128
40	1.000	1.014	1.029	1.044	1.059	1.073	1.086	1.098	1.108	1.117	1.124
50	1.000	1.013	1.027	1.042	1.056	1.070	1.083	1.094	1.105	1.113	1.120
60	0.999	1.012	1.026	1.040	1.054	1.067	1.080	1.091	1.101	1.109	1.116
70	0.998	1.011	1.024	1.038	1.051	1.064	1.076	1.087	1.097	1.105	1.113
80	0.997	1.009	1.022	1.035	1.049	1.061	1.073	1.084	1.093	1.101	1.109
90	0.995	1.007	1.020	1.033	1.046	1.058	1.069	1.080	1.088	1.097	1.105
100	0.993	1.005	1.018	1.030	1.043	1.054	1.066	1.076	1.085	1.094	1.101
110	0.991	1.003	1.015	1.027	1.039	1.051	1.062	1.072	1.882	1.090	1.097
120	0.989	1.000	1.012	1.024	1.036	1.047	1.058	1.068	1.078	1.186	1.093
130	0.986	0.997	1.009	1.021	1.033	1.044	1.055	1.064	1.074	1.082	1.089
140	0.983	0.994	1.006	1.018	1.029	1.040	1.051	1.060	1.069	1.078	1.085
150	0.980	0.991	1.003	1.014	1.026	1.036	1.047	1.056	1.065	1.074	1.081
160	0.977	0.988	0.999	1.011	1.022	1.032	1.043	1.052	1.061	1.069	1.077
170	0.974	0.985	0.996	1.007	1.018	1.028	1.039	1.048	1.057	1.065	1.073
180	0.970	0.981	0.992	1.003	1.014	1.024	1.034	1.044	1.053	1.061	1.068
190	0.967	0.977	0.988	0.999	1.009	1.020	1.030	1.040	1.048	1.057	1.064
200	0.963	0.974	0.984	0.995	1.006	1.016	1.026	1.035	1.044	1.052	1.060
210	0.959	0.970	0.980	0.991	1.001	1.011	1.021	1.031	1.040	1.048	1.056
220	0.995	0.965	0.976	0.987	0.997	1.007	1.017	1.026	1.035	1.044	1.051
230	0.951	0.961	0.972	0.982	0.992	1.003	1.012	1.022	1.031	1.039	1.047
240	0.947	0.957	0.967	0.978	0.988	0.998	1.008	1.017	1.026	1.034	1.042
250	0.942	0.952	0.963	0.973	0.983	0.993	1.003	1.012	1.021	1.030	1.038
260	0.938	0.948	0.958	0.968	0.978	0.988	0.998	1.008	1.017	1.025	1.033
270	0.933	0.943	0.953	0.963	0.973	0.983	0.993	1.003	1.012	1.020	1.029
280	0.928	0.938	0.948	0.958	0.968	0.978	0.988	0.998	1.007	1.016	1.024
290	0.923	0.933	0.943	0.953	0.963	0.973	0.983	0.993	1.002	1.011	1.019
300	0.918	0.928	0.938	0.948	0.958	0.968	0.978	0.988	0.977	1.006	1.014
310	0.913	0.923	0.933	0.943	0.953	0.963	0.973	0.983	0.992	1.001	1.010
320	0.907	0.917	0.928	0.938	0.948	0.958	0.968	0.977	0.987	0.996	1.005
330	0.902	0.912	0.922	0.932	0.942	0.952	0.962	0.972	0.982	0.991	1.000
340	0.896	0.906	0.917	0.927	0.937	0.947	0.957	0.967	0.976	0.985	0.994
350	0.890	0.900	0.911	0.921	0.931	0.941	0.951	0.961	0.971	0.980	0.989

Table 7.4: Specific Gravity at 60°F of Aqueous Ethylene Glycol Solution vs Composition *(19)*

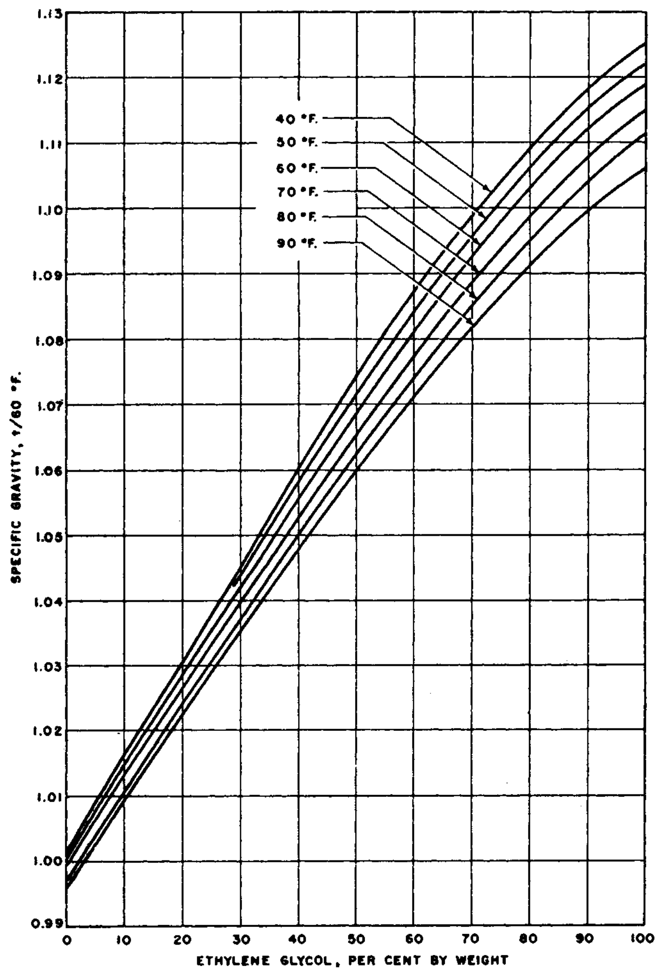


Table 7.5: Freezing Points of Aqueous Ethylene Glycol Solutions *(11)*

Ethylene Glycol		Freezing Point		Ethylene Glycol		Freezing Point	
Wt. %	Vol. %	°C	°F	Wt. %	Vol. %	°C	°F
0	0.0	0.0	32.0	40	37.8	-24	-11
2	1.8	-0.6	30.9	42	39.8	-26	-15
4	3.6	-1.3	29.7	44	41.8	-28	-18
6	5.4	-2.0	28.4	46	43.8	-31	-23
8	7.2	-2.7	27.0	48	45.8	-33	-27
10	9.1	-3.5	25.6	50	47.8	-36	-32
12	10.9	-4.4	24.0	52	49.8	-38	-37
14	12.8	-5.3	22.4	54	51.9	-41	-42
16	14.6	-6.3	20.6	56	53.9	-44	-48
18	16.5	-7.3	18.8	58	56.0	-48	-54
20	18.4	-8	17	80	78.9	-47	-52
22	20.3	-9	15	82	81.0	-43	-46
24	22.2	-11	12	84	83.1	-40	-40
26	24.1	-12	10	86	85.2	-36	-33
28	26.0	-13	8	88	87.3	-33	-27
30	28.0	-15	5	90	89.4	-29	-21
32	29.9	-17	2	92	91.5	-26	-15
34	31.9	-18	-1	94	93.6	-23	-9
36	33.8	-20	-4	96	95.8	-19	-3
38	35.8	-22	-7	98	97.9	-16	+3
				100	100.0	-13	+9

Table 7.6: Specific Heat of Aqueous Ethylene Glycol Solutions *(32)*

	Ethylene Glycol Percentage										
By Wt.	0	10	20	30	40	50	60	70	80	90	100
By Vol.	0	9.1	18.4	28.0	37.8	47.8	58.0	68.4	78.9	89.4	100
Temp. °F	Specific Heat in Btu/lb. °F										
60	0.9996	0.968	0.928	0.882	0.835	0.785	0.734	0.687	0.642	0.599	0.556
70	0.9987	0.968	0.930	0.887	0.841	0.792	0.742	0.695	0.650	0.606	0.563
80	0.9982	0.969	0.933	0.892	0.847	0.799	0.750	0.703	0.658	0.613	0.570
90	0.9980	0.970	0.935	0.896	0.852	0.822	0.758	0.711	0.665	0.620	0.575
100	0.9980	0.971	0.938	0.900	0.858	0.813	0.766	0.719	0.672	0.627	0.581
110	0.9982	0.972	0.940	0.904	0.863	0.819	0.773	0.727	0.680	0.634	0.588
120	0.9985	0.973	0.942	0.907	0.868	0.825	0.780	0.734	0.687	0.640	0.594
130	0.9989	0.974	0.944	0.910	0.872	0.851	0.787	0.740	0.694	0.647	0.600
140	0.9994	0.975	0.947	0.914	0.877	0.837	0.794	0.747	0.700	0.653	0.606
150	1.0001	0.977	0.949	0.917	0.881	0.842	0.800	0.753	0.707	0.659	0.612
160	1.0008	0.978	0.951	0.921	0.886	0.847	0.805	0.759	0.713	0.666	0.619
170	1.0017	0.980	0.954	0.924	0.890	0.852	0.810	0.765	0.720	0.673	0.625
180	1.0027	0.981	0.956	0.927	0.894	0.857	0.816	0.771	0.726	0.679	0.631
190	1.0039	0.983	0.959	0.931	0.898	0.861	0.821	0.777	0.733	0.686	0.637
200	1.0052	0.985	0.961	0.934	0.902	0.866	0.826	0.783	0.739	0.692	0.644
210	1.0067	0.987	0.964	0.937	0.905	0.870	0.831	0.789	0.745	0.698	0.650
220	1.008	0.989	0.966	0.940	0.909	0.875	0.836	0.794	0.750	0.704	0.656
230	1.010	0.992	0.969	0.943	0.913	0.879	0.841	0.799	0.756	0.710	0.662
240	1.013	0.994	0.972	0.947	0.917	0.884	0.846	0.805	0.762	0.716	0.668
250	1.015	0.997	0.976	0.951	0.922	0.889	0.852	0.811	0.768	0.723	0.675
260	1.018	1.000	0.979	0.954	0.926	0.893	0.857	0.817	0.774	0.729	0.681
270	1.021	1.003	0.983	0.958	0.930	0.898	0.862	0.822	0.780	0.735	0.687
280	1.024	1.006	0.986	0.962	0.935	0.903	0.867	0.828	0.786	0.741	0.693
290	1.027	1.010	0.990	0.966	0.939	0.908	0.873	0.834	0.792	0.747	0.700
300	1.030	1.014	0.994	0.970	0.943	0.913	0.878	0.840	0.798	0.754	0.706
310	1.034	1.018	0.998	0.975	0.948	0.918	0.883	0.845	0.804	0.760	0.712
320	1.039	1.023	1.003	0.980	0.953	0.923	0.889	0.851	0.810	0.766	0.718
330	1.044	1.028	1.008	0.985	0.958	0.928	0.894	0.857	0.816	0.772	0.724
340	1.050	1.033	1.013	0.990	0.963	0.933	0.900	0.863	0.822	0.778	0.731
350	1.056	1.038	1.018	0.995	0.968	0.939	0.906	0.869	0.828	0.784	0.737

Table 7.7: Vapor-Liquid Composition Curves for Aqueous Ethylene Glycol Solutions *(23)*

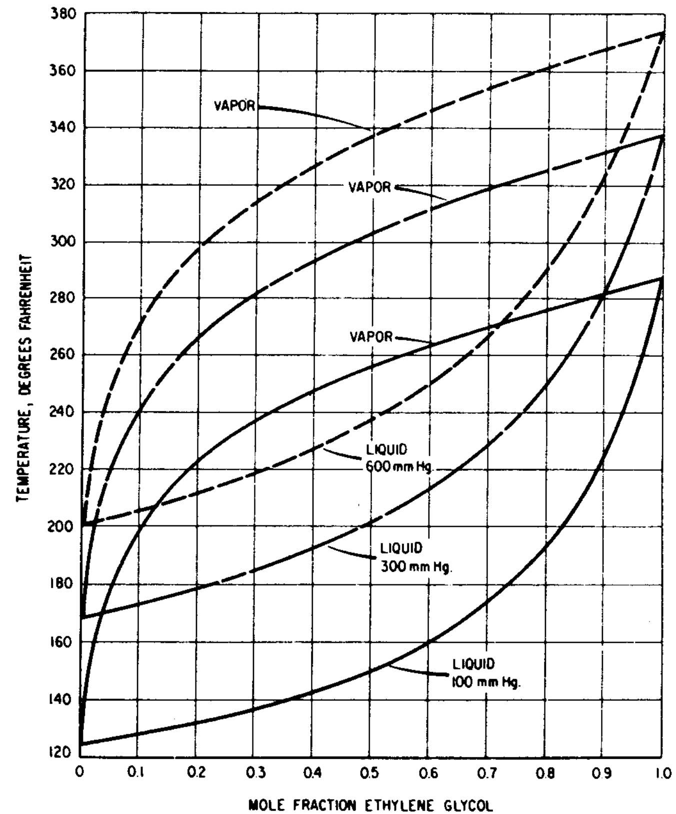


Table 7.8: Vapor Pressure of Aqueous Ethylene Glycol Solutions *(11)*

	Ethylene Glycol Percentage							
By Wt.	70	75	80	85	90	95	97	100
By Vol.	68.4	73.6	78.9	84.1	89.4	94.7	96.8	100
Temp. °F	Absolute Pressure in psi							
150	2.2	2.0	1.7	1.4	1.1	0.6	0.4	0.04
160	2.9	2.6	2.2	1.8	1.4	0.8	.5	.06
170	3.6	3.2	2.8	2.3	1.7	1.0	.7	.08
180	4.5	4.1	3.5	2.9	2.2	1.3	.8	.12
190	5.6	5.1	4.4	3.6	2.7	1.6	1.0	.16
200	7.0	6.3	5.5	4.5	3.4	2.0	1.3	0.2
210	8.5	7.7	6.7	5.5	4.1	2.4	1.6	.3
220	10.4	9.4	8.2	6.7	5.0	3.0	2.0	.4
230	12.6	11.4	9.9	8.2	6.1	3.6	2.5	.5
240	15.2	13.7	11.9	9.9	7.4	4.4	3.0	.7
250	18.1	16.4	14.3	11.8	8.9	5.3	3.7	0.9
260	21.6	19.5	17.0	14.1	10.6	6.4	4.4	1.1
270	25.5	23.0	20.1	16.7	12.6	7.6	5.3	1.4
280	30.1	27.1	23.7	19.7	14.9	9.1	6.4	1.8
290	35.2	31.8	27.9	23.2	17.6	10.8	7.6	2.3
300	41.1	37.1	32.5	27.1	20.6	12.7	9.0	2.8
310	47.7	43.1	37.8	31.5	24.0	14.9	10.6	3.5
320	55.2	49.9	43.8	36.6	27.9	17.4	12.5	4.3
330	63.5	57.5	50.5	42.2	32.3	20.2	14.6	5.2
340	72.9	66.0	58.0	48.5	37.2	23.5	17.1	6.3
350	83.3	75.5	66.4	55.6	42.7	27.1	19.8	7.6

Table 7.9: Viscosity of Aqueous Ethylene Glycol Solutions *(19)*

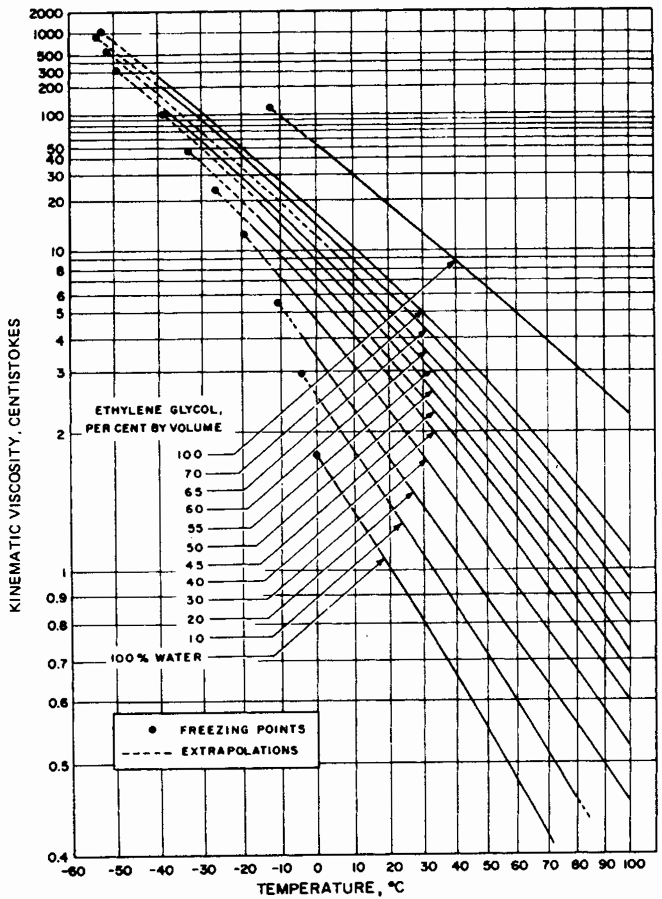


Table 7.10: Relative Humectant Values of Aqueous Solutions of Ethylene Glycol *(17)*

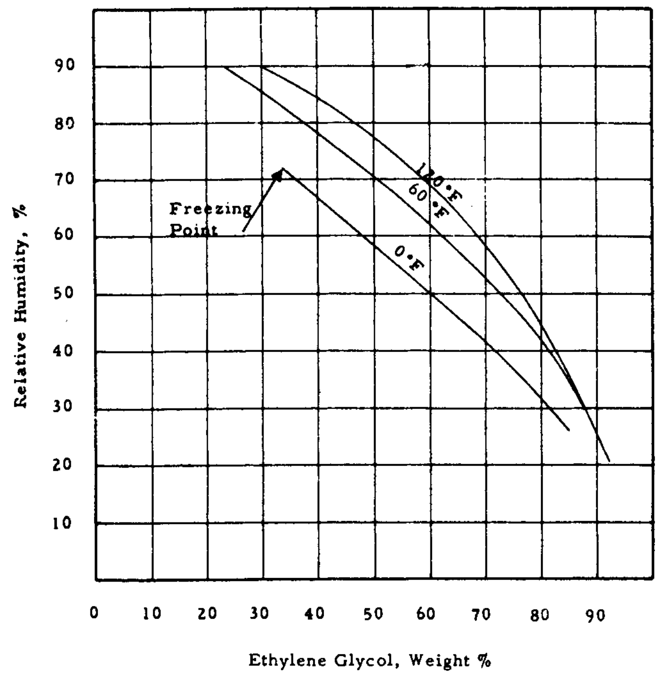


Table 7.11: Water Vapor Dew Points Over Aqueous Ethylene Glycol Solutions *(23)*

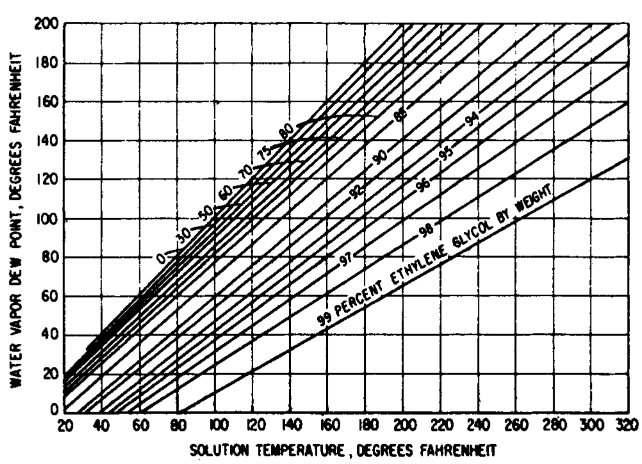
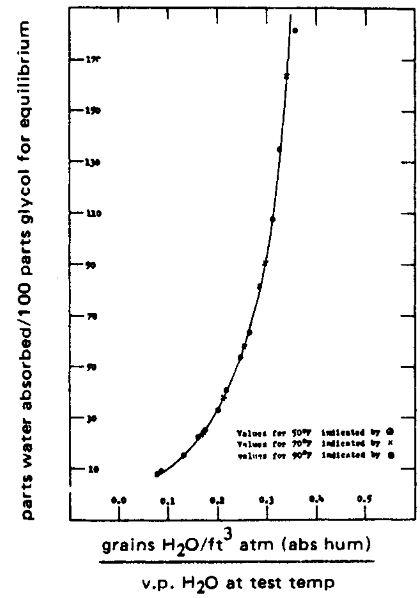
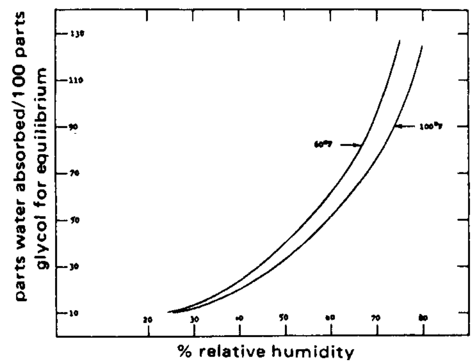


Table 7.12: Key Hygroscopicity Curve for Ethylene Glycol *(55)*



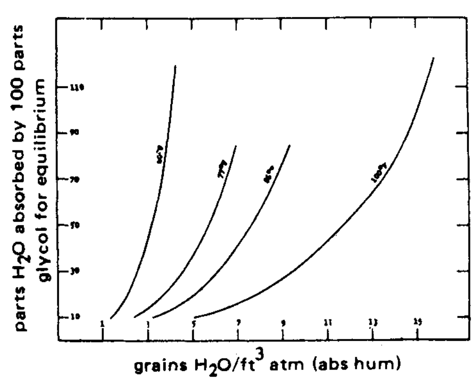
Key hygroscopicity curve for ethylene glycol showing influence of vapor pressure of water at test temperature on amounts of moisture absorbed by ethylene glycol for system equilibrium at various temperatures and various absolute humidities.

Table 7.13: Moisture Absorption of Ethylene Glycol at Various Relative Humidities *(55)*

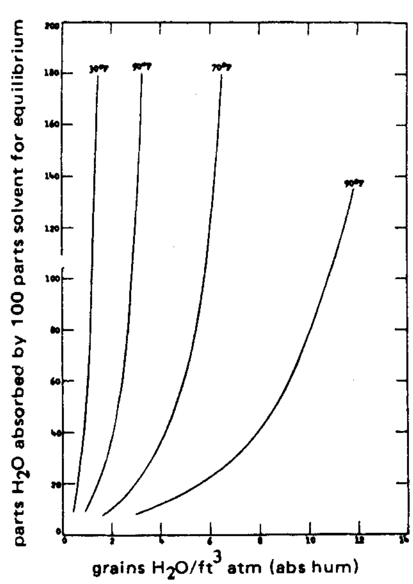


The effect of temperature on the moisture absorption of ethylene glycol for system equilibrium at various relative humidities. Values plotted were calculated from those of the key hygroscopicity curve for ethylene glycol.

Table 7.14: Moisture Absorption of Ethylene Glycol at Various Absolute Humidities *(55)*



The effect of temperature on the moisture absorption of ethylene glycol for system equilibrium at various absolute humidities. Values used were calculated from those in key hydroscopicity curve for ethylene glycol.



The effect of temperature on the moisture absorption of ethylene glycol for system equilibrium of various absolute humidities. Values plotted were from experimentally obtained data.

Table 7.15: Kinematic Viscosity of Anhydrous Ethylene Glycol and Trimethylene Glycol Solutions *(32)*

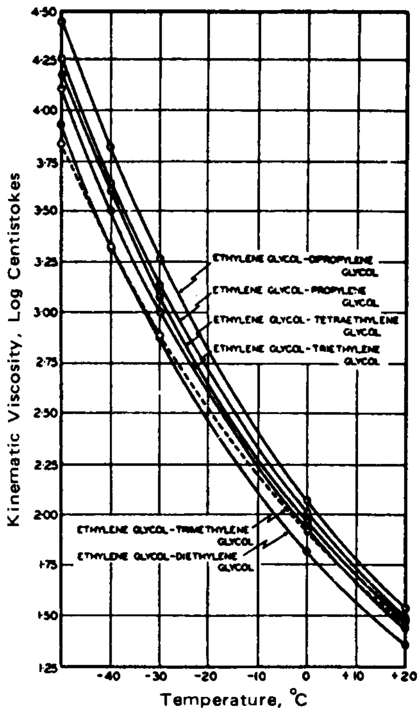


Table 7.16: Freezing Points of Anhydrous Ethylene Glycol and Trimethylene Glycol Solutions *(32)*

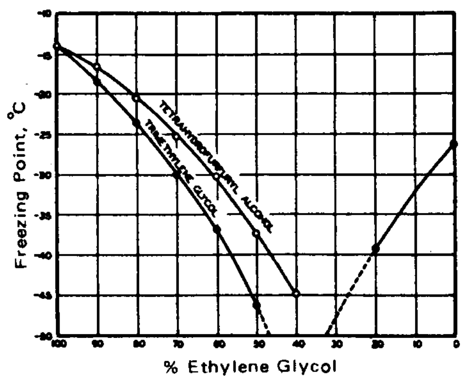


Table 7.17: Azeotropes of Ethylene Glycol *(19)*

Components			Azeotrope					
Compound	Specific Gravity at 20/20° C	Boiling Point, °C at 760 mm.	Boiling Point, °C at 760 mm.	Composition, % by wt. In Azeotrope	In Upper Layer	In Lower Layer	Relative Volume of Layers at 20° C	Sp. Gr. 20/20° C of Azeotrope or Layers
Ethylene Glycol Butyl Carbitol	1.1155 0.9536	197.5 230.6	196.2	72.5 27.5				1.074
Ethylene Glycol Dibutyl Ether	1.1155 0.7694	197.5 142.1	139.5	6.4 93.6	2 98	99 1	U 95 L 5	U 0.777 L 1.114
Ethylene Glycol Dichlorethyl Ether	1.1155 1.2220	123† 96†	92.7†				U 9.9 L 90.1	
Ethylene Glycol Diethyl Carbitol	1.1155 0.9082	197.5 188.4	178.0	26.1 73.9				0.959
Ethylene Glycol Di(2-ethylhexyl) Ether)	1.1155 0.8121	91‡ 135‡	87‡				U 50 L 50	
Ethylene Glycol Di-N-hexyl Ether	1.1155 0.7942	123† 137†	112.8†	35.6 64.4	0.1 99.9	99.9 0.1	U 71.8 L 28.2	U 0.795 L 1.115
Ethylene Glycol Diphenyl Ether	1.1155 1.0677#	123† 161†	120.4†	62.3 37.7	0.2 99.8	98.5 1.5	U 37.6 L 62.4	U 1.076 L 1.114
Ethylene Glycol Diphenyl Ether	1.1155 1.0677#	197.5 257.4	192.3	64.5 35.5	0.22 99.78	98.28 1.72	U 35.3• L 64.7•	U 1.068# L 1.108#

(continued)

Table 7.17: (continued)

Components			Azeotrope					
Compound	Specific Gravity at 20/20° C	Boiling Point, °C at 760 mm.	Boiling Point, °C at 760 mm.	Composition, % by wt. In Azeotrope	In Upper Layer	In Lower Layer	Relative Volume of Layers at 20° C	Sp. Gr. 20/20° C of Azeotrope or Layers
Ethylene Glycol Exthoxydiglycol	1.1155 0.9898	197.5 208.8	192	45.5 54.5				1.050
Ethylene Glycol Methyl Carbitol	1.1155 1.0211	123† 115†	114	4 96				1.025
Ethylene Glycol Methyl Carbitol	1.1155 1.0211	157.1▲ 151.2▲	149▲	12 88				1.033
Ethylene Glycol Methyl Carbitol	1.1155 1.0211	197.5 193.6	192	30 70				1.051

†At 50 mm. Hg
‡At 10 mm. Hg
Heterogeneous at 20° C
#At 30/20° C
•At 30° C
▲At 200 mm. Hg

PROPYLENE GLYCOL

1,2-Propanediol $CH_3CHOHCH_2OH$

Table 7.18: Physical Properties of Propylene Glycol *(32)*

Boiling point at 10 mm. Hg 50 mm. Hg 760 mm. Hg	85° C 116° C 187.4° C
ΔBoiling point/Δpressure	0.042° C/mm.Hg
Coefficient of expansion to 20° C to 55° C	0.695×10^{-3} 0.743×10^{-3}
Evaporation rate (n-butyl acetate—1.0)	0.01
Fire point, ASTM open cup	225° F
Flash point, Cleveland open cup	210° F
Freezing point	-60 (sets to glass below this temperature)
Heat of combustion at 25° C	5728 cal./g. 10,312 Btu/lb.
Heat of vaporization at boiling point at 1 atm.	168.9 cal./g. 304 Btu/lb.
Ignition temperature	421° C
Molecular weight, calculated	76.094
Pour point	-59.5° C
Refractive index, n_D 20° C	1.4326
Specific heat at 20° C	0.593 cal./g./°C
Specific gravity, 20/20° C	1.0381
Δ Specific gravity/Δtemperature, 0 to 40° C	0.00073/°C
Vapor density (air—1.0)	2.52
Vapor pressure at 20° C	0.05 mm. Hg 0.08 mm. Hg
Viscosity at 0° C 20° C 40° C	243 cp. 56 cp. 18 cp.
Weight per gallon at 25° C	8.64 lb.

Table 7.19: Propylene Glycol Specifications *(19)*

	Standard Grade	U.S.P. Grade	Air-Treatment Grade	Special Grade
Specific gravity at 20/20° C	1.0370 to 1.0390	1.0375 to 1.0400	1.0375 to 1.0400	1.0380 to 1.0390
Distillation at 760 mm. Hg	Lbp, 185° C, max. 95 ml. 109° C, max. Dp, 194° C, max.	†	†	‡
Propylene glycol, min.	–	97.5% by wt.	97.5% by wt.	99.0% by wt.
Acidity, max.	0.005% by wt.§	0.005% by wt.§	0.005% by wt.§	0.005% by wt.#
Refractive Index at 20° C, n_D	–	–	1.4316 to 1.4335	–
Solubility	–	●	▲	–
Chlorides, max. (as Cl)	0.001% by wt.	0.001% by wt.	0.001% by wt.	0.001% by wt.
Oxidizing substances	–	–	–	none
Carbonyl groups	–	–	–	shall pass test
Sulfates	–	none	–	–
Heavy metals, max. (as Pb)	–	5 ppm	–	–
Lead, max. (as Pb)	–	–	–	0.0003% by wt.**
Arsenic, max. (As_2O_3)	–	1 ppm	–	0.001% by wt.††
Water, max.	0.5% by wt.	0.2% by wt.	0.5% by wt.	–
Ash, max.	0.005% by wt.	0.005% by wt.	0.007% by wt.	–
Color, max. (Pt-Co Scale)	10	10	15	15
Odor	–	mild	–	mild
Suspended matter	substantially free	substantially free	substantially free	substantially free

†Shall entirely distill within a 5° C range which shall include 187.3° C.
‡Shall entirely distill within a 5° C range, and 90 ml. shall distill within a 2.2° C range.
§Calculated as acetic acid. This is equivalent to 0.047 mg. KOH per g. sample.
#Calculated as hydrochloric acid. This is equivalent to 0.077 mg. KOH per g. sample.
●Miscible in all proportions with water, acetone, and chlorform at 25° C.
▲Completely miscible in all proportions with water at 20° C.
**This is equivalent to 3 ppm.
††This is equivalent to 10 ppm.

Table 7.20: Boiling Points of Aqueous Propylene Glycol Solutions *(19)*

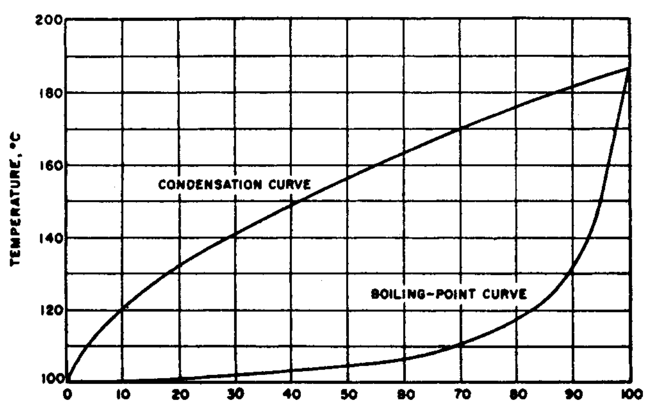


Table 7.21: Conversion Chart for Aqueous Propylene Glycol Solutions *(23)*

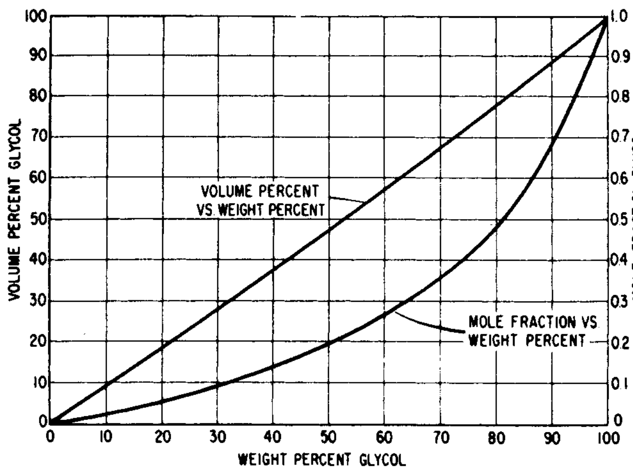


Table 7.22: Density of Aqueous Propylene Glycol Solutions (Percent by Weight) *(23)*

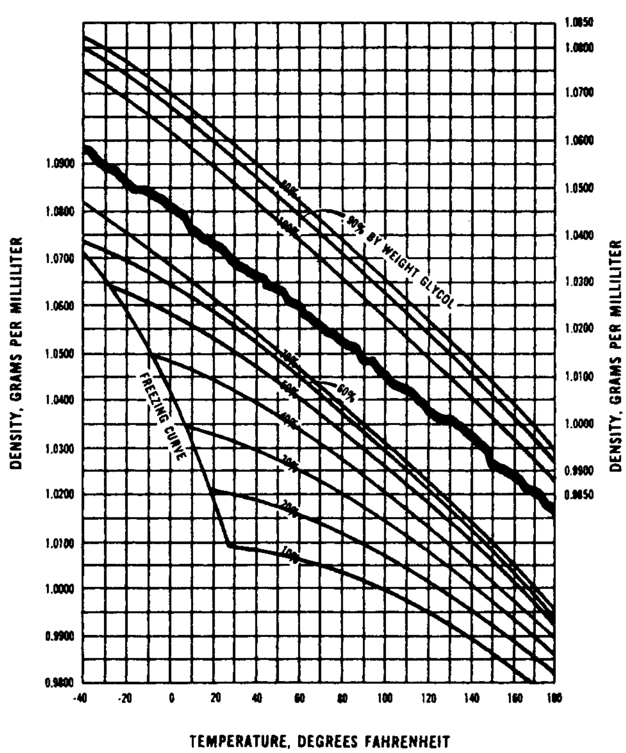


Table 7.23: Effect of Aqueous Propylene Glycol Solutions on Dew Points at Various Contact Temperatures *(19)*

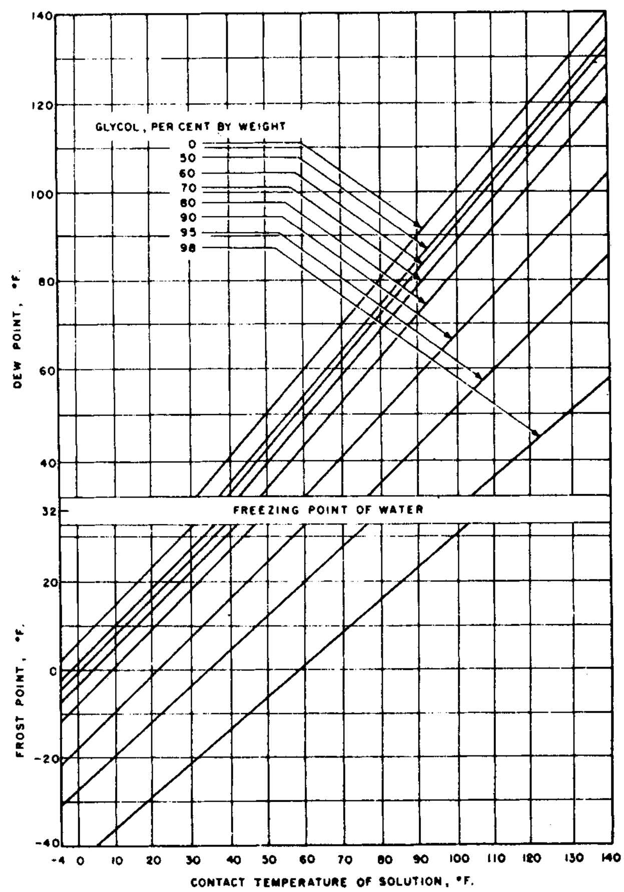
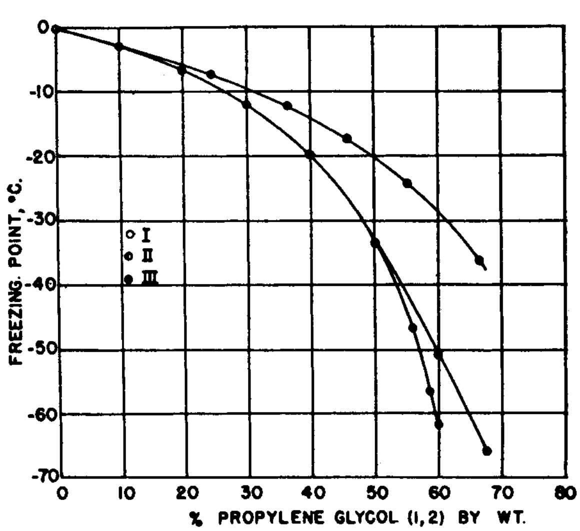


Table 7.24: Freezing Points of Aqueous Propylene Glycol Solutions *(2)*



(I) Observed;
(II) Theoretical, without hydration;
(III) Theoretical, with complete hydration.

Table 7.25: Heat of Vaporization of Propylene Glycol at Various Temperatures *(19)*

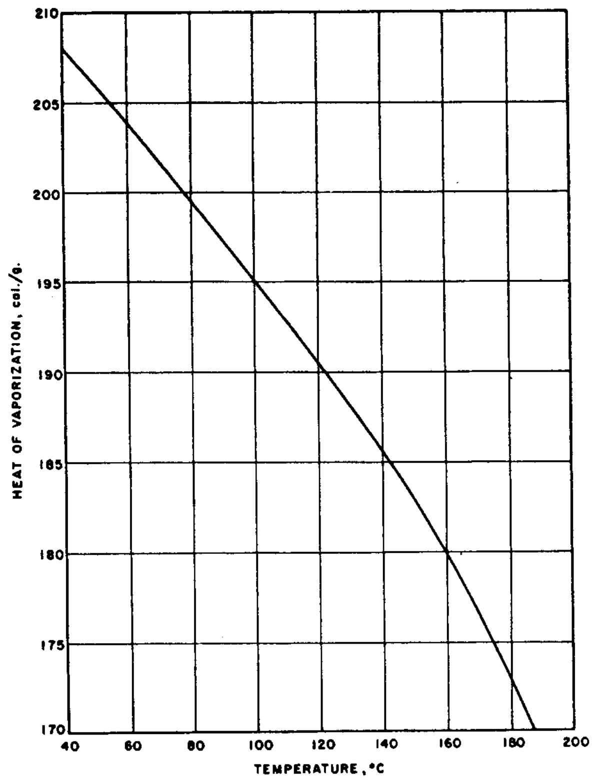


Table 7.26: Refractive Indices of Aqueous Propanediol Solutions at 20°, 30°, and 40°C *(32)*

1,2-Propanediol				1,3-Propanediol			
Glycol, %	n_D^{20}	n_D^{30}	n_D^{40}	Glycol, %	n_D^{20}	n_D^{30}	n_D^{40}
9.94	1.3435	1.3422	1.3411	10.98	1.3433	1.3430	1.3410
20.03	1.3552	1.3540	1.3522	19.96	1.3540	1.3528	1.3511
30.23	1.3670	1.3650	1.3630	30.21	1.3654	1.3640	1.3623
40.01	1.3780	1.3758	1.3732	40.34	1.3770	1.3755	1.3735
49.41	1.3887	1.3863	1.3833	49.94	1.3880	1.3861	1.3839
60.04	1.3995	1.3970	1.3940	60.32	1.3997	1.3975	1.3951
69.50	1.4082	1.4055	1.4028	70.24	1.4103	1.4080	1.4065
79.43	1.4174	1.4144	1.4111	79.87	1.4205	1.4183	1.4155
89.74	1.4252	1.4221	1.4190	89.68	1.4300	1.4276	1.4250
100	1.4324	1.4295	1.4255	100	1.4389	1.4364	1.4332

Table 7.27: Relative Humectant Values of Propylene Glycol, N.F. *(23)*

values are given as the per cent by weight of glycol in water solutions that will be in equilibrium with air of various temperatures and humidities

Temperature of Air	RELATIVE HUMIDITIES							
	20%	30%	40%	50%	60%	70%	80%	90%
0° F	93.0	88.0	78.0	73.7	70.0	62.5	45.0	
10° F	93.5	87.5	78.0	73.7	70.5	63.0	46.0	30.0
20° F	93.0	87.5	78.5	73.7	71.0	63.0	47.0	30.0
30° F	92.7	88.0	79.5	74.0	71.0	62.0	48.0	30.0
40° F	93.0	89.5	81.0	76.0	71.5	64.0	50.0	30.0
50° F	93.5	90.5	83.0	77.5	72.0	66.0	51.0	31.0
60° F	93.7	90.8	84.0	78.0	72.0	66.0	52.0	32.0
70° F	94.0	91.0	85.0	78.5	73.0	66.5	52.5	33.0
80° F	94.3	91.2	85.0	79.0	73.0	66.0	52.5	34.0
90° F	94.4	91.2	85.5	79.5	73.5	67.0	53.0	35.0
100° F	94.4	91.25	85.8	80.5	74.0	67.0	53.0	35.0
110° F	94.4	91.26	86.0	81.0	75.0	67.5	53.0	33.0
120° F	94.4	91.27	86.5	81.3	75.0	68.0	54.0	33.0

Table 7.28: Specific Gravity of Aqueous Propylene Glycol Solutions at Various Temperatures *(19)*

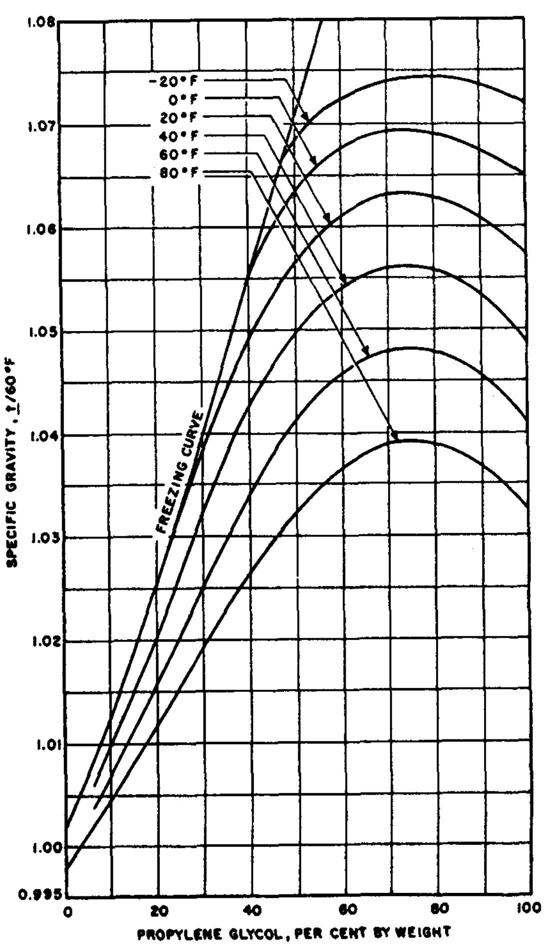


Table 7.29: Specific Heat of Aqueous Propylene Glycol Solutions *(19)*

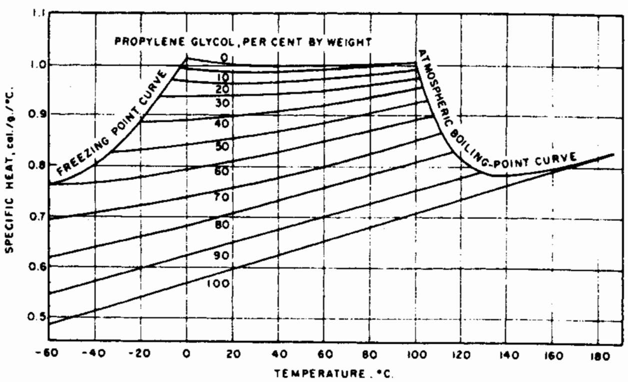


Table 7.30: Thermal Conductivity of Aqueous Propylene Glycol Solutions at Various Temperatures *(19)*

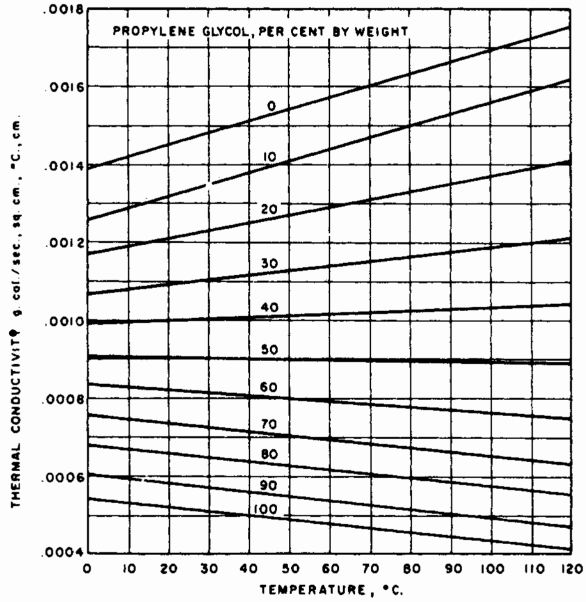


Table 7.31: Total Pressure over Aqueous Propylene Glycol Solutions Versus Temperatures *(23)*

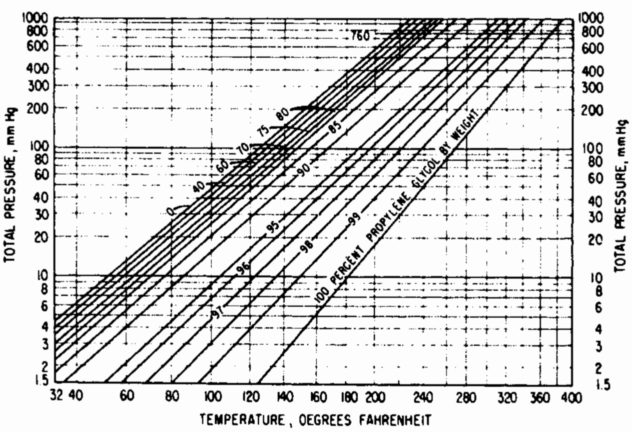


Table 7.32: Vapor-Liquid Composition Curves for Aqueous Propylene Glycol Solutions *(23)*

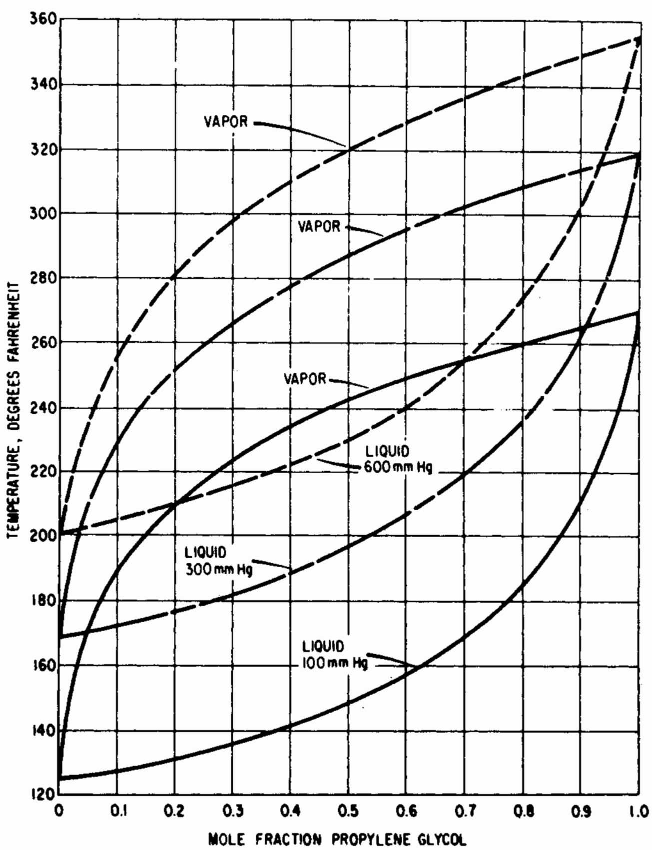


Table 7.33: Vapor Pressures of Aqueous Propylene Glycol Solutions *(19)*

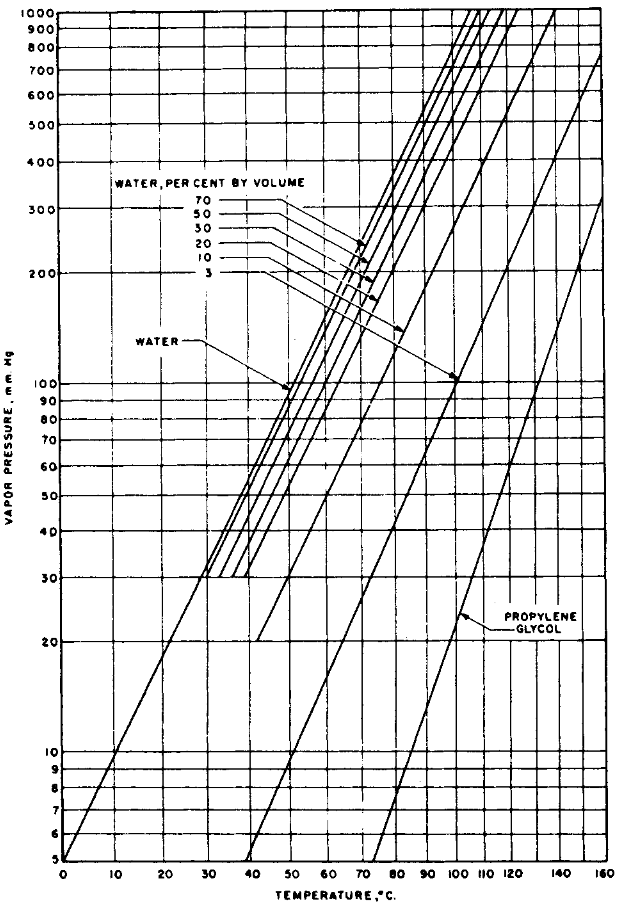


Table 7.34: Viscosities of Aqueous Propylene Glycol Solutions *(23)*

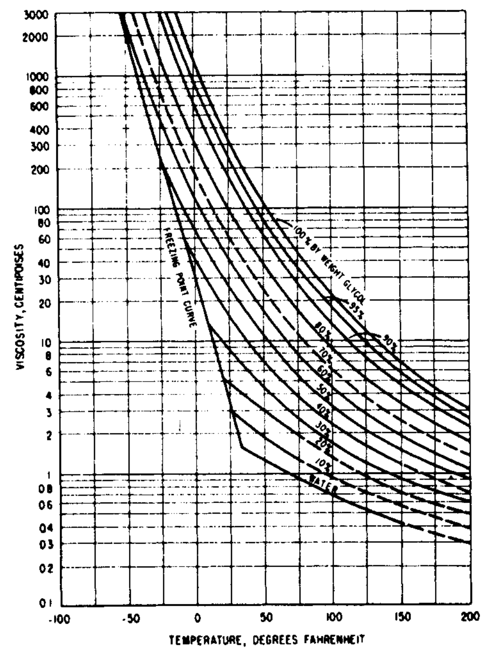


Table 7.35: Azeotropes of Propylene Glycol *(19)*

Components			Azeotrope		
Compound	Specific Gravity at 20/20° C	Boiling Point, °C at 760 mm. Hg	Boiling Point, °C at 760 mm. Hg.	Relative Volume of Layers at 20° C	Specific Gravity at 20/20° C
Propylene glycol dibutyl ether	1.0381 0.7694	187.4 142.1	136	Upper layer 93 Lower layer 7	
Propylene glycol di-(2-ethylhexy) ether	1.0381 0.8121	85† 135†	84†		
Propylene glycol toluene	1.0381 0.8683	187.4 110.6	108	Upper layer 98 Lower layer 2	

†At 10 mm. Hg.
‡Heterogeneous at 20° C.

1,3-PROPANEDIOL

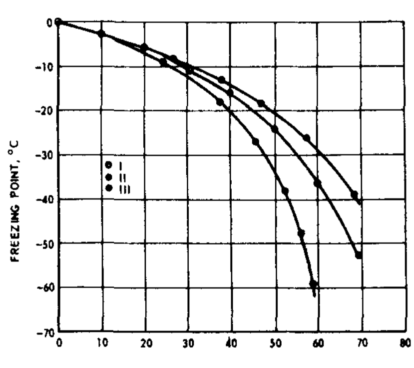
Trimethylene Glycol
1,3-Dihydroxypropane
Beta-Propylene Glycol

$CH_2OHCH_2CH_2OH$

Table 7.36: Physical Properties of 1,3-Propanediol *(32)*

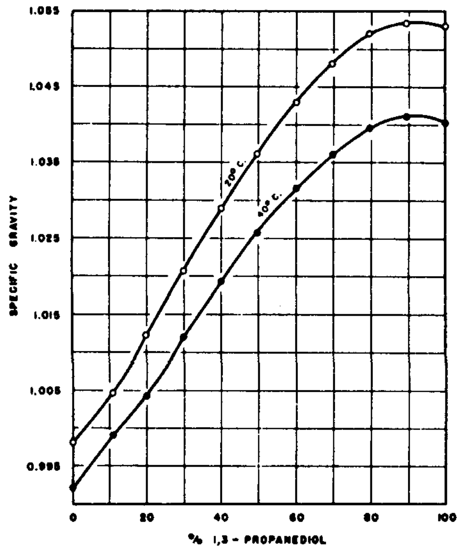
Boiling point at 760 mm. Hg	214° C (210-211° C)		
Freezing points of aqueous solutions, °C			
10%	-2.86		
20%	-6.5		
30%	-11.8		
40%	-18.8		
50%	-27.7		
60%	-40.0		
Molecular weight	78.1		
Refractive indices of aqueous solutions at 20, 30, and 40° C	n_D^{20}	n_D^{30}	n_D^{40}
11.0%	1.3433	1.3430	1.3410
20.0%	1.3540	1.3528	1.3511
30.2%	1.3654	1.3640	1.3623
40.3%	1.3770	1.3755	1.3735
50.0%	1.3880	1.3861	1.3839
60.3%	1.3997	1.3975	1.3951
70.2%	1.4103	1.4080	1.4065
79.9%	1.4205	1.4183	1.4155
89.7%	1.4300	1.4276	1.4250
100.0%	1.4389	1.4364	1.4332
Specific gravity at 20/20° C	1.0554		
at 0° C	1.0625		
at 214° C	0.9028		
Thermal expansion of aqueous solutions between 20 and 40° C ($\alpha \times 10^3$)			
20%	0.39		
40%	0.47		
60%	0.55		
80%	0.60		
100%	0.61		
Isothermal contraction in volume on mixing with water between 20 and 40° C (ml. contraction per 100 ml. of initial volume)	20° C	40° C	
20%	0.37	0.29	
40%	0.90	0.81	
60%	1.19	1.07	
80%	1.01	0.89	

Table 7.37: Freezing Points of Aqueous Solutions of 1,3-Propanediol *(32)*



Freezing Points of Propylene Glycol (1,3)-Water Mixtures. (I) Observed; (II) Theoretical, without hydration; (III) Theoretical, with complete hydration.

Table 7.38: Specific Gravity of Aqueous Solutions of 1,3-Propanediol at 20° and 40°C *(32)*



1,2-BUTANEDIOL

Table 7.39: Physical Properties of 1,2-Butanediol *(32)*

Freezing points of aqueous solutions, °C	
10%	-2.6
20%	-6.0
30%	-11.0
40%	-16.5
50%	-22.4
60%	-29.0

Refractive indices of aqueous solutions at 20, 30, and 40° C	n_D^{20}	n_D^{30}	n_D^{40}
10.13%	1.3452	1.3436	1.3420
19.69%	1.3572	1.3553	1.3534
29.72%	1.3693	1.3672	1.3650
39.79%	1.3813	1.3788	1.3760
49.68%	1.3920	1.3892	1.3865
59.88%	1.4027	1.4000	1.3966
69.37%	1.4120	1.4090	1.4058
79.73%	1.4211	1.4185	1.4165
69.40%	1.4297	1.4265	1.4230
100.0%	1.4375	1.4347	1.4310

Viscosity of aqueous solutions at 20 and 40° C, in centistokes	20° C	40° C
10.125%	1.520	0.910
19.7%	2.187	1.243
29.7%	3.319	1.690
39.8%	4.802	2.311
49.7%	6.739	3.088
59.9%	9.72	4.227
36.4%	13.82	5.744
79.7%	21.37	8.372
89.4%	35.54	12.59
100.0%	68.0	21.25

Thermal expansion of aqueous solutions between 20 and 40° C (α x 10^3)	
20%	0.454
40%	0.654
60%	0.726
80%	0.765
100%	0.775

Isothermal concentration in volume on mixing with water between 20 and 40° C (ml. contraction per 100 ml. of initial volume)	20° C	40° C
20%	1.12	1.01
40%	1.96	1.67
60%	1.92	1.65
80%	1.27	1.10

Table 7.40: Specific Gravity of Aqueous 1,2-Butanediol Solutions at 20° and 40°C *(32)*

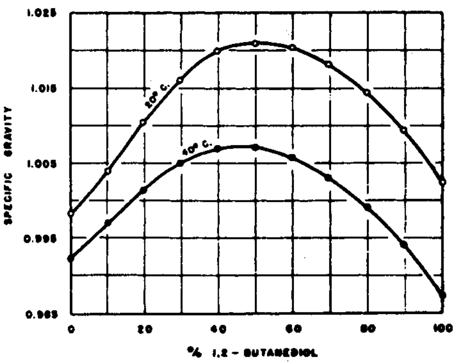
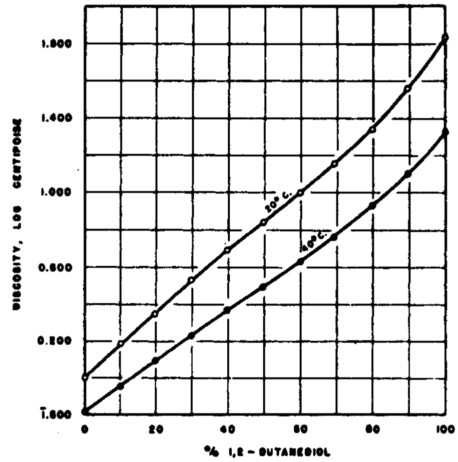


Table 7.41: Absolute Viscosity of Aqueous 1,2-Butanediol Solutions at 20° and 40°C *(32)*



1,3-BUTANEDIOL

1,3-Butylene Glycol $CH_3CH(OH)CH_2CH_2OH$

Table 7.42: Physical Properties of 1,3-Butanediol *(32)*

Acid as acetic	0.005% by wt., max.	Refractive index at 20° C/D	1.4401
Boiling point	207.5° C	Solubility (% by weight)	
		in castor oil	18%
Color, APHA	15, max.	in ether	7%
		either in	9%
Distillation range	200-215° C	in ethyl acetate	32%
		ethyl acetate in	41%
Flash point, tag open cup	250° F	in dibutyl phthalate	2%
Freezing point	Below -50° C	Specific gravity at 20/20° C	1.0062
Heat of vaporization	155 cal./g.	Surface tension at 25° C	37.8 dynes/cm.
Hygroscopicity, weight % water absorbed in 144 hours at:		Vapor pressure at 20° C	0.06 mm. Hg
25-28° C and 81% relative humidity	38.5	Viscosity at 25° C	104 cp.
25-28° C and 47% relative humidity	12.5	at 35° C	89 cp.
25-28 C and 20% relative humidity	4.3		
		Water	0.5% by wt., max.
Molecular weight, calculated	90.12		
		Weight per gallon at 20° C	8.38 lb.
Purity	95% by wt., min.		

Table 7.43: Freezing Point of Aqueous Solutions of 1,3-Butanediol *(32)*

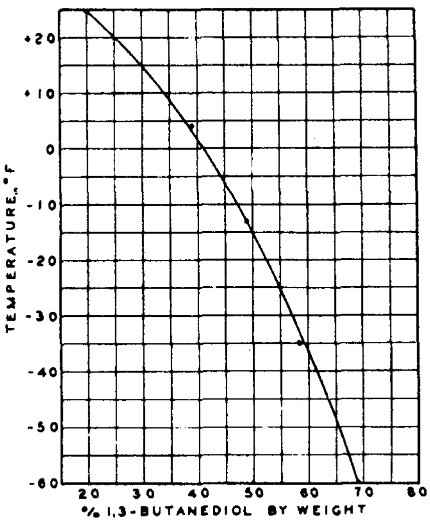


Table 7.44: Refractive Index and Freezing Point of Aqueous Solutions of 1,3-Butanediol *(32)*

Content of 1,3-Butanediol, % by Weight	$n^{25°C}_D$	Freezing Point °C	Freezing Point °F
19.4	1.3561	-4	+25
39.4	1.3806	-15.5	+4
49.3	1.3922	-25	-13
58.5	1.4032	-37	-35
64.5	1.4093	-42	-44
69.0	1.4138	-51	-60
79.5	1.4237	Viscous liquid	
89.0	1.4319		

Table 7.45: Specific Gravity of Aqueous 1,3-Butanediol solutions at 20° and 40°C *(32)*

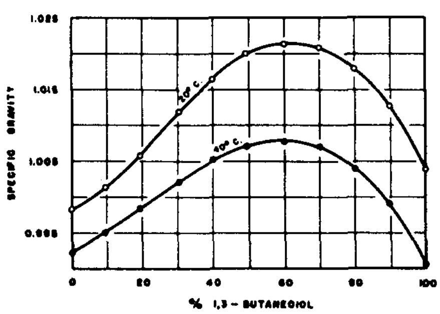
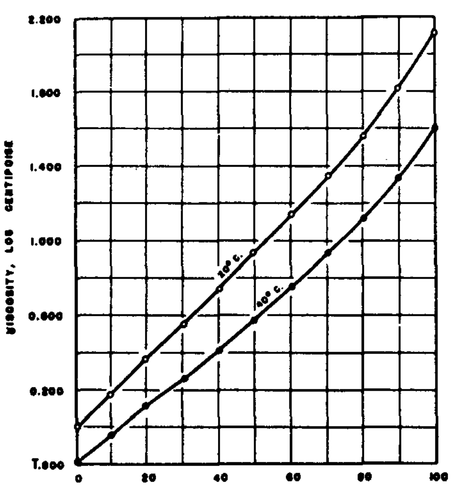


Table 7.46: Viscosity of Aqueous Solutions of 1,3-Butanediol *(32)*

Content of 1,3-Butanediol, % by Weight	Viscosity, centipoises 25.0° C	-171° ± C	-37 ± 1° C
19.4	2.1		
39.4	4.7		
49.3	6.7	95	
58.5	10.2	172	
69.0	16.7	304	
79.5	27.7	620	7,000
89.0	50.8	1,360	18,500
100.0	98.3	3,150	35,000

Table 7.47: Absolute Viscosity of Aqueous 1,3-Butanediol Solutions at 20° and 40°C *(32)*



1,4-BUTANEDIOL

Tetramethylene Glycol $HOCH_2CH_2CH_2CH_2OH$

Table 7.48: Physical Properties of 1,4-Butanediol *(32)*

Acetals (as CH_2O)	Less than 0.8%
Acidity (as HCO_2H)	Less than 1%
Ash	0%
Boiling range	221-231° C
1-Butanol	Less than 0.5%
Flash point (ASTM open cup)	More than 250° F
Free aldehyde as CH_2O	Less than 0.1%
Freezing point range	18-19.5° C
Purity	Over 96%
Refractive index, n_D^{25}	1.4435-1.4445
Specific gravity, d_4^{25}	1.012-1.016
Unsaturation (as butendiol)	Less than 1%
Viscosity, 25° C	65-70 cp.
Water content	Less than 0.8%

Pure 1,4-Butanediol

Boiling point at 10 mm. Hg	118° C
20 mm. Hg	133° C
100 mm. Hg	170° C
200 mm. Hg	187° C
760 mm. Hg	228° C

Freezing point	20.9° C
Refractive index, n_D^{25}	1.4446
Solubility at 25° C (g./100 ml. solvent)	
in water	Infinite
in methanol	Infinite
in ethanol	Infinite
in acetone	Infinite
benzene	0.3
carbon tetrachloride	0.4
chlorobenzene	0.4
ethyl acetate	14.1
ethyl ether	3.1
petroleum ether (35-60° C)	0.9
Specific gravity, d_4^{25}	1.0154

% Water in 1,4-Butanediol	Freezing Point (°C)	Viscosity (cp. at 25° C)
0.0	20.0	71.5
0.1	19.8	71.3
0.5	19.0	70.2
1.0	18.1	68.9

Table 7.49: Absolute Viscosity of Aqueous 1,4-Butanediol Solutions at 20° and 40°C *(32)*

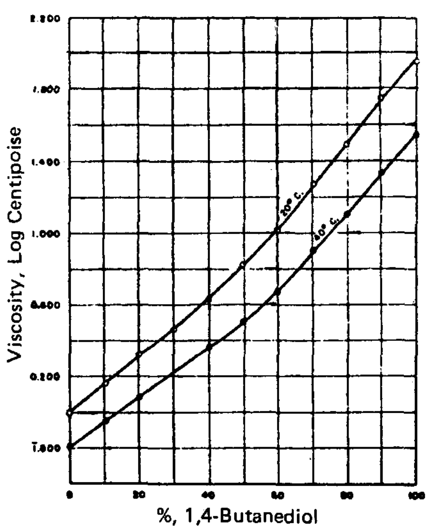
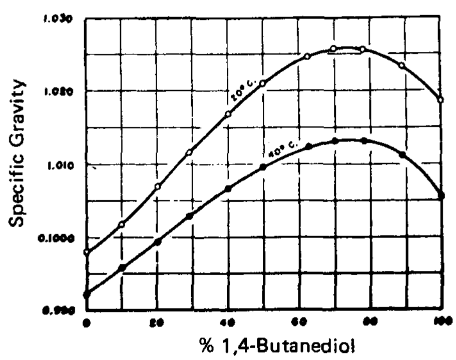


Table 7.50: Specific Gravity of Aqueous 1,4-Butanediol Solutions at 20° and 40°C *(32)*



2,3-BUTANEDIOL

2,3-Butylene Glycol
2,3-Dihydroxybutane

$CH_3CH(OH)\cdot CH(OH)CH_3$

Table 7.51: Physical Properties of 2,3-Butanediol *(32)*

Acidity as acetic	0.005% by wt., max.
Boiling point at 760 mm. Hg	182.5° C
Color, APHA	15 max.
Density of liquid	1.048
Distillation range	175-195° C
Flash point, tag open cup	185° F
Freezing point	19° C (5% water lowers F. P. to +10° C)
Hygroscopicity (% water pickup-400 hrs.)	
25° C and 50% rel. hum.	24
25° C and 75% rel. hum.	33
Molecular weight	90.12
Purity	95% by wt., min.
Refractive index, n_D^{20}	1.4377
Solubility (1% by weight)	
in castor oil	78%
in ether	5%
ether in	5%
in ethyl acetate	14%
ethyl acetate in	9%
in dibutyl phthalate	2%
Specific gravity at 20/20° C	1.0093
Specific heat at 30° C	0.60 cal./g.
Specific tension at 25° C	36 dynes/cm.
Vapor pressure at 20° C	17 mm. Hg
Viscosity at 25° C	121 cp.
at 35° C	90 cp.
Water content	0.5% by wt., max.
Weight per gallon	8.41 lb.

Table 7.52: Boiling Points of Aqueous levo-2,3-Butanediol Solutions at Atmospheric Pressure *(32)*

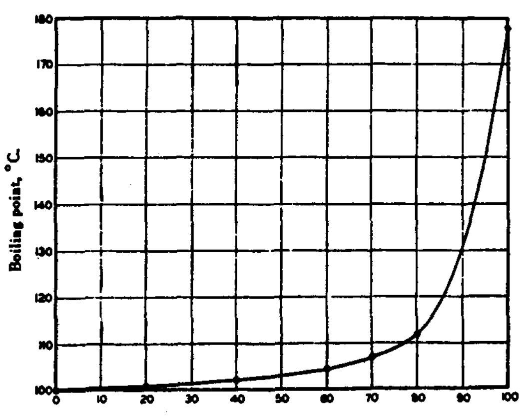


Table 7.53: Boiling Points of Aqueous levo-2,3-Butanediol-Ethanol Solutions *(32)*

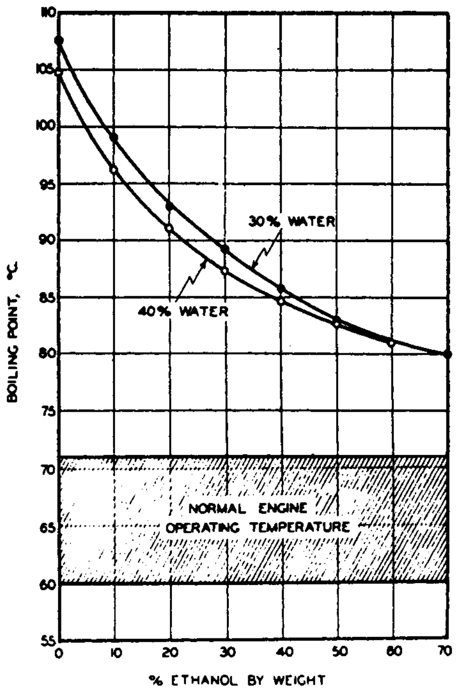


Table 7.54: Boiling Points of Aqueous levo-2,3-Butanediol-Methanol Solutions *(32)*

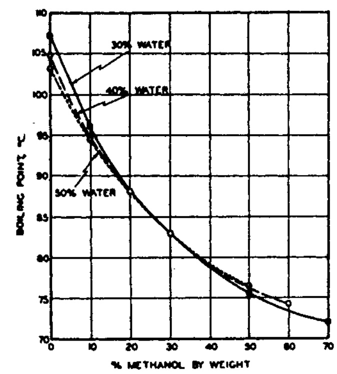


Table 7.55: Freezing Points of Aqueous levo-2,3-Butanediol Solutions *(32)*

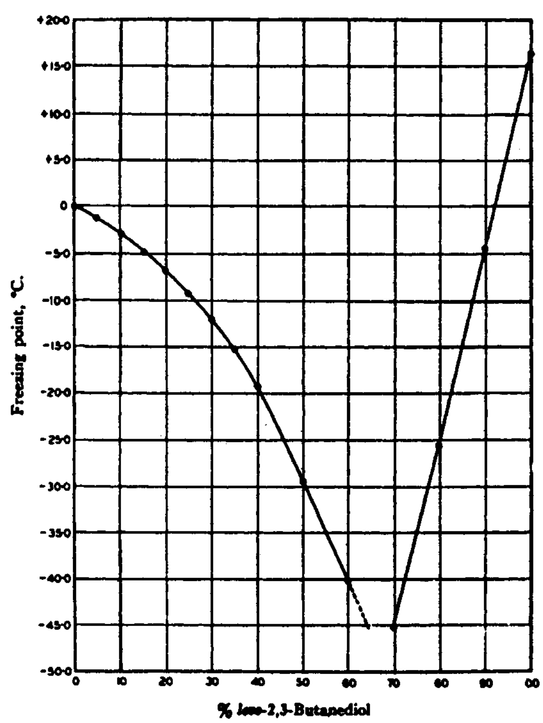


Table 7.56: Freezing Points of Aqueous meso-dextro-2,3-Butanediol Solutions *(32)*

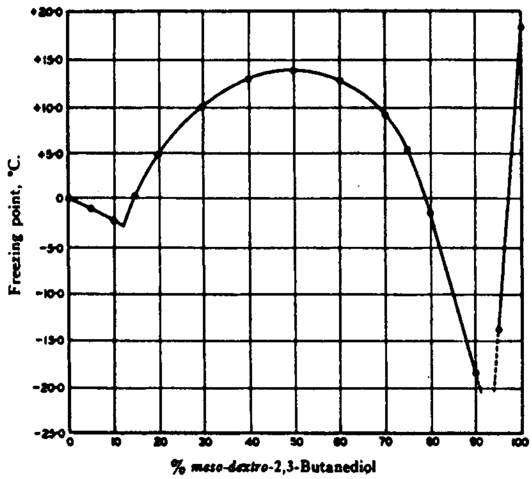


Table 7.57: Effect of meso-2,3-Butanediol on the Freezing Point of Aqueous levo-2,3-Butanediol Solutions *(32)*

Composition of Diol	40% Water	60% Water
100% levo	-40.4° C	-19.4° C
95% levo 5% meso	-37.0	-21.0
90% levo 10% meso	-28.2	-21.0
85% levo 15% meso	-18.6	-17.2
80% levo 20% meso	-14.0	-12.4
50% levo 50% meso	+1.55	+1.55

Table 7.58: Freezing Points of Aqueous levo-2,3-Butanediol-Ethanol Solutions *(32)*

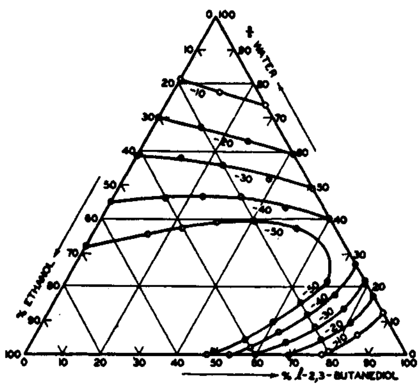


Table 7.59: Freezing Points of Aqueous levo-2,3-Butanediol-Ethylene Glycol Solutions *(32)*

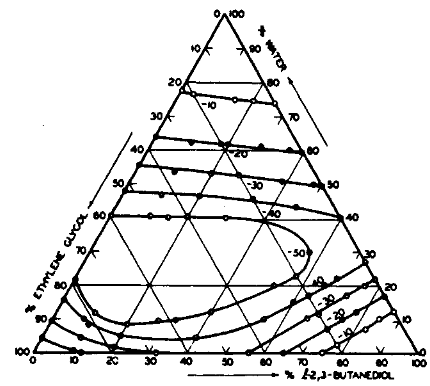


Table 7.60: Freezing Points of Aqueous levo-2,3-Butanediol-Methanol Solutions *(32)*

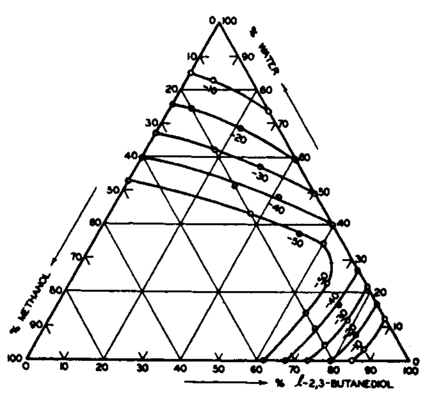


Table 7.61: Freezing Points of Aqueous levo-2,3-Butanediol-Tetrahydrofurfuryl Alcohol Solutions *(32)*

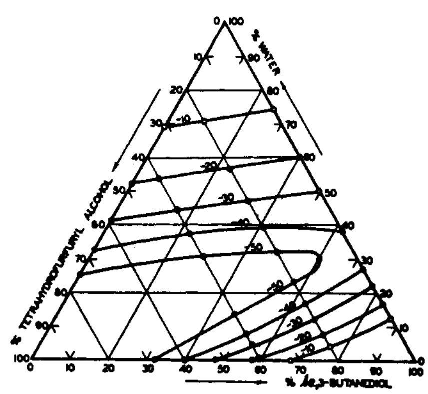


Table 7.62: Kinematic Viscosity of Aqueous levo-2,3-Butanediol Solutions, Expressed Logarithmically, as a Function of Concentration and Temperature *(32)*

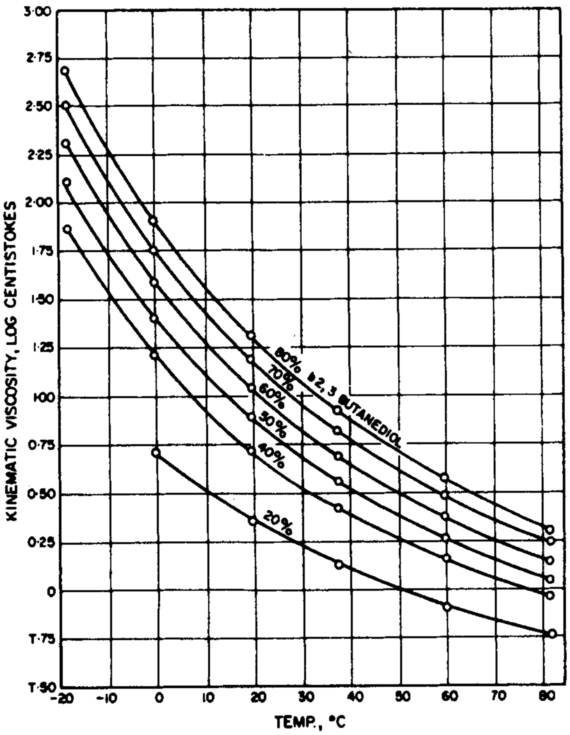


Table 7.63: Kinematic Viscosity of Aqueous levo-2,3-Butanediol Solutions in Relation to Concentration and Temperature *(32)*

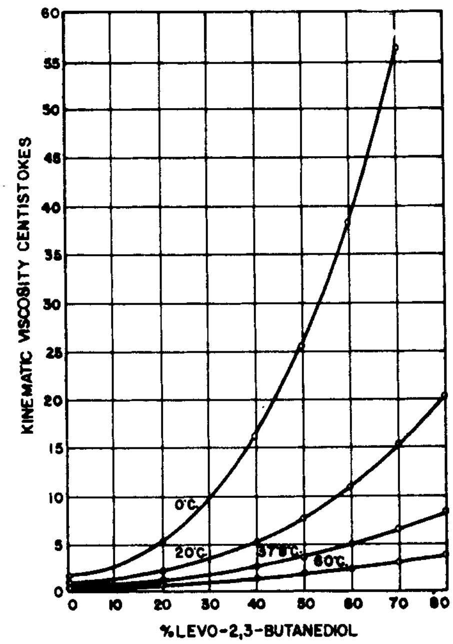


Table 7.64: Kinematic Viscosity of 60% levo-2,3-Butanediol, Glycerol and Ethylene Glycol Solutions at Low Temperatures *(32)*

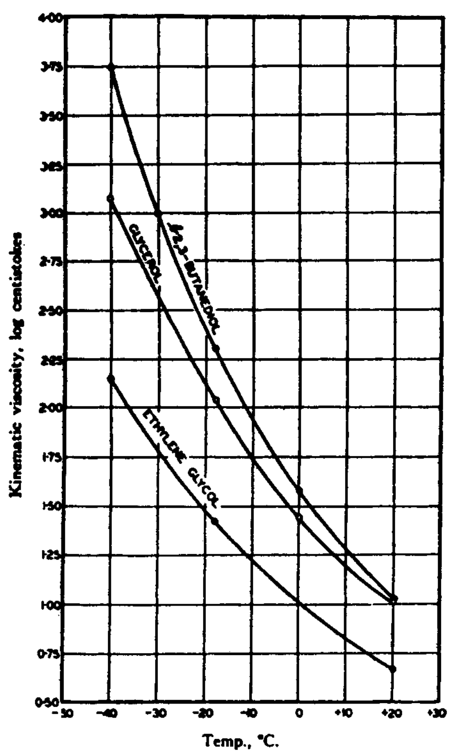


Table 7.65: Kinematic Viscosity of Aqueous levo-2,3-Butanediol-Ethanol Solutions at 20°C, Expressed in Centistokes *(32)*

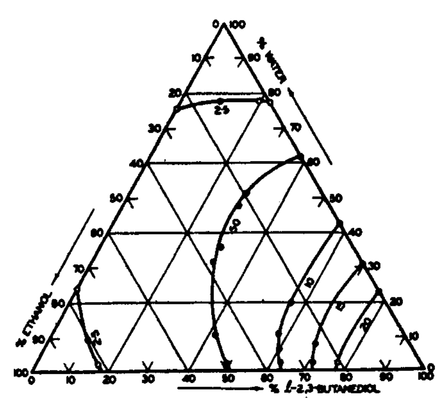


Table 7.66: Kinematic Viscosity of Aqueous levo-2,3-Butanediol-Methanol Solutions at 20°C, Expressed in Centistokes *(32)*

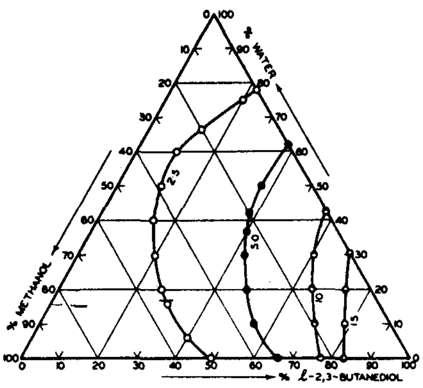


Table 7.67: Kinematic Viscosity of Aqueous levo-2,3-Butanediol-Ethylene Glycol Solutions in 20°C, Expressed in Centistokes *(32)*

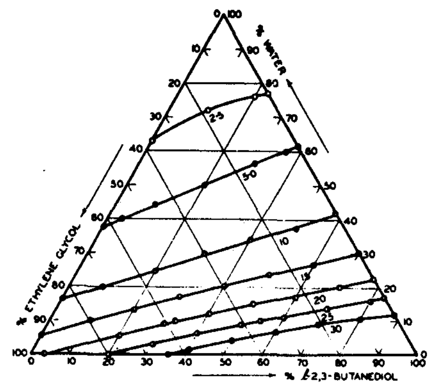


Table 7.68: Kinematic Viscosity of Aqueous levo-2,3-Butanediol-Tetrahydrofurfuryl Alcohol Solutions at 20°C, Expressed in Centistokes *(32)*

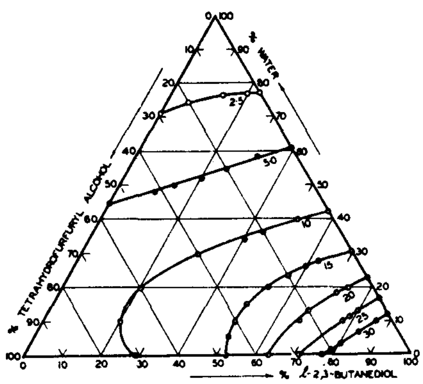


Table 7.69: Absolute Viscosity of Aqueous Solutions of Ethylene Glycol, levo-2,3-Butanediol, meso-dextro-2,3-Butanediol and Glycerol at 20°C *(32)*

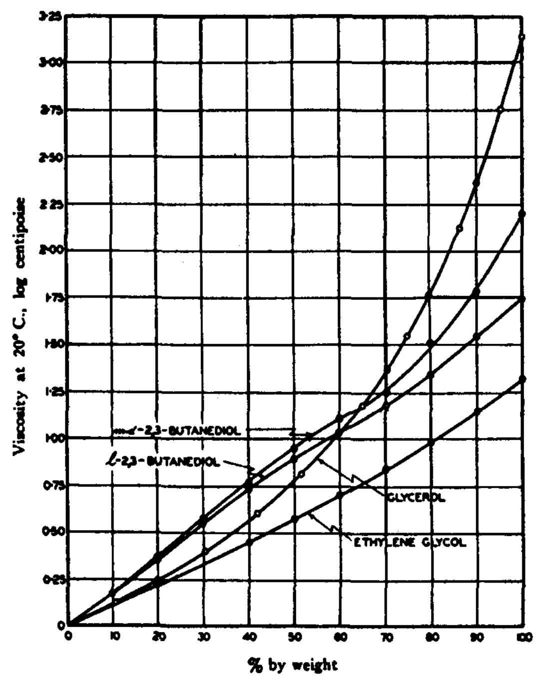


Table 7.70: Optical Rotatory Power of Aqueous levo-2,3-Butanediol Solutions at 20°C *(32)*

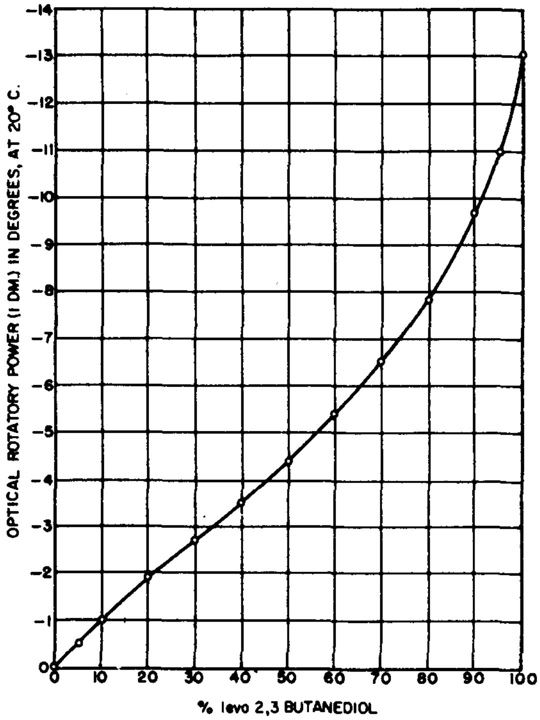


Table 7.71: Effects of Concentration and Temperature on the Specific Rotatory Power of Aqueous levo-2,3-Butanediol Solutions *(32)*

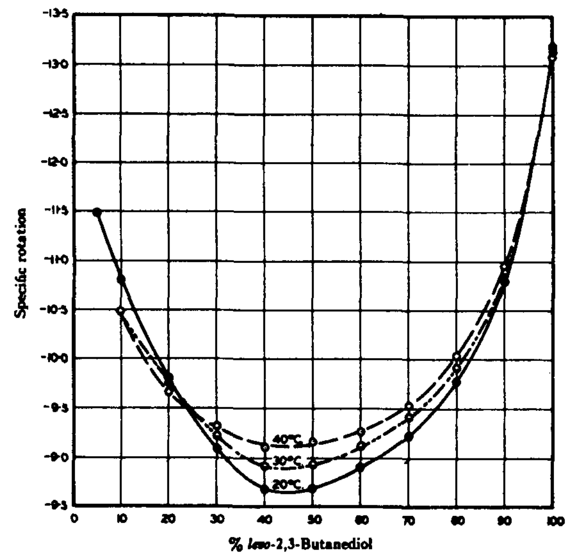


Table 7.72: Refractive Indices of Aqueous levo-2,3-Butanediol Solutions at Different Temperatures *(32)*

Diol, %	Temperature, °C			
	20	25	30	35
0	1.3330	1.3325	1.3319	1.3312
10.0	1.3450	1.3445	1.3437	1.3429
19.9	1.3574	1.3566	1.3557	1.3549
29.9	1.3700	1.3689	1.3677	1.3666
39.9	1.3820	1.3807	1.3793	1.3779
49.9	1.3930	1.3915	1.3900	1.3885
59.6	1.4027	1.4012	1.3997	1.3982
70.0	1.4115	1.4098	1.4082	1.4065
79.7	1.4197	1.4180	1.4162	1.4146
89.7	1.4264	1.4247	1.4229	1.4212
99.5	1.4322	1.4302	1.4283	1.4264

Table 7.73: Refractive Indices of Aqueous Solutions of meso- and levo-2,3-Butanediol at 25°C *(32)*

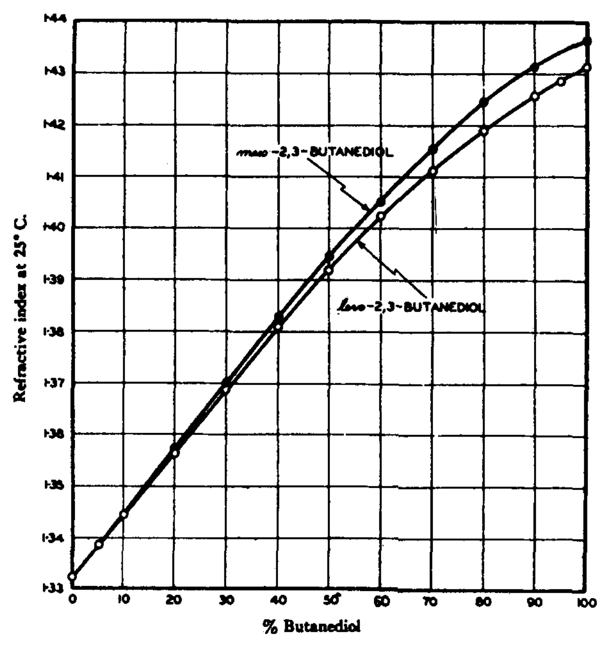


Table 7.74: Specific Gravity of Aqueous levo-2,3-Butanediol Solutions at 20°, 30°, and 40°C *(32)*

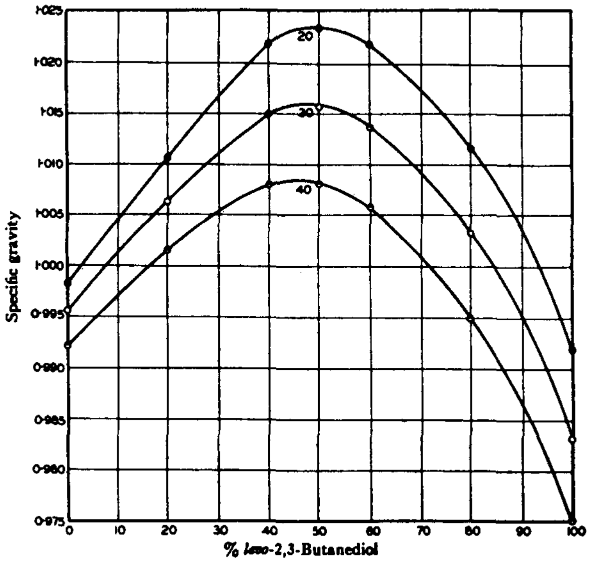


Table 7.75: Specific Gravity of Aqueous meso-2,3-Butanediol Solutions at 20°, 30°, and 40°C *(32)*

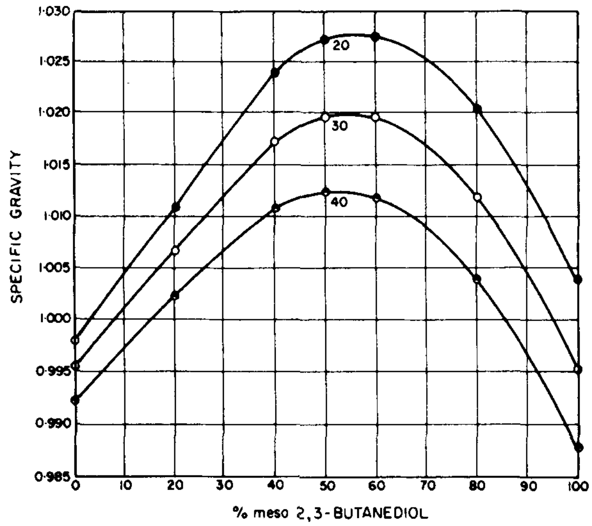
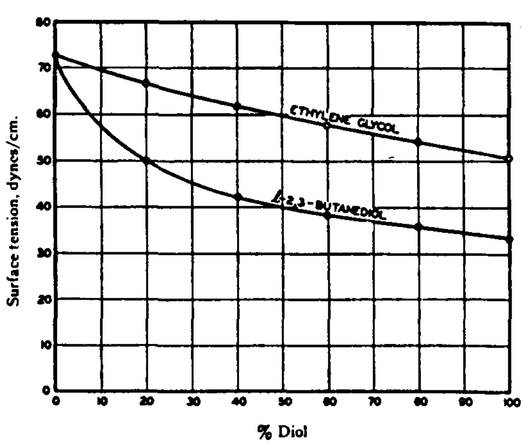


Table 7.76: Surface Tension of Aqueous Solutions of levo-2,3-Butanediol and Ethylene Glycol *(32)*



BUTANEDIOLS

Table 7.77: Refractive Indices of Aqueous Butanediol Solutions at 20°, 30°, and 40°C *(32)*

1,2-Butanediol				1,3-Butanediol				1,4-Butanediol			
Glycol, %	n_D^{20}	n_D^{30}	n_D^{40}	Glycol, %	n_D^{20}	n_D^{30}	n_D^{40}	Glycol, %	n_D^{20}	n_D^{30}	n_D^{40}
10.13	1.3452	1.3436	1.3420	9.51	1.3442	1.3430	1.3417	10.51	1.3444	1.3432	1.3420
19.69	1.3572	1.3553	1.3534	19.18	1.3552	1.3548	1.3520	20.01	1.3563	1.3550	1.3532
29.72	1.3693	1.3672	1.3650	30.20	1.3688	1.3670	1.3649	30.02	1.3682	1.3671	1.3659
39.79	1.3813	1.3788	1.3760	39.94	1.3800	1.3778	1.3755	39.86	1.3802	1.3790	1.3768
49.68	1.3920	1.3892	1.3865	49.45	1.3920	1.3895	1.3870	49.70	1.3935	1.3918	1.3898
59.88	1.4027	1.4000	1.3966	60.02	1.4040	1.4012	1.3983	59.95	1.4052	1.4042	1.4020
69.37	1.4120	1.4090	1.4058	70.10	1.4145	1.4118	1.4090	70.15	1.4183	1.4167	1.4140
79.73	1.4212	1.4185	1.4165	80.20	1.4242	1.4215	1.4185	79.85	1.4283	1.4258	1.4236
89.40	1.4297	1.4265	1.4230	89.67	1.4323	1.4295	1.4264	90.10	1.4370	1.4349	1.4318
100	1.4375	1.4347	1.4310	100	1.4398	1.4370	1.4331	100	1.4451	1.4425	1.4395

Table 7.78: Kinematic Viscosity of Aqueous Butanediol Solutions at 20° and 40°C, in Centistokes *(32)*

1,2-Butanediol			1,3-Butanediol			1,4-Butanediol		
Glycol, %	Viscosity		Glycol, %	Viscosity		Glycol, %	Viscosity	
	20°C	40°C		20°C	40°C		20°C	40°C
10.125	1.520	0.910	9.505	1.51	0.91	10.51	1.446	0.89
19.69	2.187	1.243	19.175	2.295	1.291	20.01	2.109	1.218
29.72	3.310	1.690	30.20	3.529	1.818	30.02	2.867	1.6602
39.79	4.802	2.311	39.94	5.419	2.593	39.86	4.258	2.382
49.685	6.739	3.088	49.45	8.313	3.695	49.70	6.57	3.202
59.88	9.72	4.227	60.02	13.44	5.600	59.95	10.20	4.707
69.37	13.82	5.744	70.1	21.57	8.413	70.15	18.48	7.982
79.73	21.37	8.372	80.20	35.36	12.88	79.85	30.63	12.62
89.40	35.54	12.57	89.67	63.43	21.21	90.1	54.35	21.40
100	68.0	21.25	100	129.8	39.70	100	87.62	33.8

2-BUTENE-1,4-DIOL

$$HOCH_2CH{=}CHCH_2OH$$

Table 7.79: Physical Properties of 2-Butene-1,4-diol *(32)*

Physical Properties of Technical Cis-2-Butene-1,4-Diol		Purified Cis-2-Butene-1,4-Diol	
Boiling point range	232-235° C	Boiling point at 760 mm. Hg	234° C
		100 mm. Hg	177° C
Fire point (Cleveland open cup)	270° F	20 mm. Hg	140° C
		10 mm. Hg	122° C
Flash point (Cleveland open cup)	263° F	5 mm. Hg	109° C
Freezing point range	4.0-7.0° C	Freezing point	12.5° C
Molecular weight	88.1	Refractive index, n_D^{25}	1.4768-1.4773
Refractive index, n_D^{25}	1.476-1.478	Specific gravity at 25/15° C	1.070
Specific gravity at 25/15° C	1.067-1.074		
Viscosity at 68° F	22 cp.		
100° F	10.8 cp.		
210° F	2.5 cp.		

2-BUTYNE-1,4-DIOL

$HOCH_2C{\equiv}CCH_2OH$

Table 7.80: Physical Properties of 2-Butyne-1,4-Diol *(32)*

Physical Properties of Commercial 2-Butyne-1,4-Diol

Acetals (as CH_2O)	Less than 0.6%
Aldehydes (as CH_2O)	Less than 0.5%
Butynediol content	35 ± 1%
Freezing point	Less than -7° C
Methanol (by distillation)	0.0%
pH	4 to 6
Propargyl alcohol	Less than 0.5%
Saponification No. (as mg. KOH/g. product)	Less than 6
Specific gravity, d_4^{25}	1.04 to 1 --
Weight per gallon	8.7 lb.

Purified 2-Butyne-1,4-Diol

Boiling point at 10 mm. Hg	140° C
100 mm. Hg	194° C
Crystal structure	
system	Orthorhombic
principal forms	Basal pinacoids and prisms with crystals flattened parallel to the basal pinacoids
Melting point	57.5° C
Refractive indices n_D^{25}	α ± 1.450 - 0.002
	β ± 1.528 - 0.002
Solubility (g./100 ml. solvent)	
in water at 0° C	121
in water at 25° C	374
in ethyl alcohol at 25° C	83
in acetone at 25° C	70
in ethyl ether at 25° C	2.6
in benzene at 25° C	0.04

1,5-PENTANEDIOL

Pentamethylene Glycol $HOCH_2CH_2CH_2CH_2CH_2OH$

Table 7.81: Physical Properties of 1,5-Pentanediol *(32)*

Boiling point at 760 mm. Hg	242.5° C
50 mm. Hg	166° C
10 mm. Hg	134° C
Coefficient of expansion at 55° C	0.00061/°C
Flash point (open cup)	265° F
Freezing point	-15.6° C
Molecular weight	104.16
Refractive index at 20° C	1.4489
Specific gravity at 20/20° C	0.9921
Surface tension at 20° C	43.2 dynes/cm.
Vapor pressure at 20° C	Less than 0.01
Viscosity at 0° C (absolute)	415 cp.
20° C	128 cp.
40° C	48 cp.
Weight per gallon at 20° C (average)	8.23 lb.

Table 7.82: Absolute Viscosity of Aqueous 1,5-Pentanediol Solutions at 20° and 40°C *(32)*

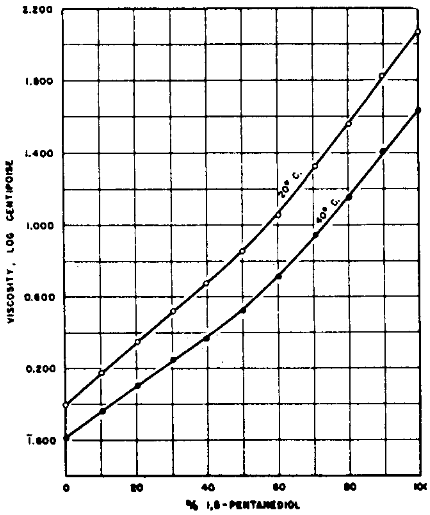
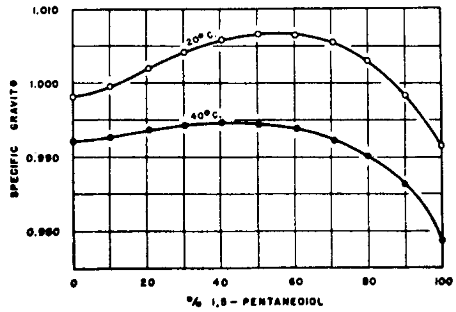


Table 7.83: Specific Gravity of Aqueous 1,5-Pentanediol Solutions at 20° and 40°C *(32)*



2,4-PENTANEDIOL

Amylene Glycol — $CH_3CHOHCH_2CHOHCH_3$

Table 7.84: Physical Properties of 2,4-Pentanediol *(32)*

Boiling point at 760 mm. Hg	199° C
Flash point, Cleveland open cup	210° F
Melting point	45° C
Molecular weight	104.15
Specific gravity (apparent), 20/20° C	0.964 (supercooled liquid)

NEOPENTYL GLYCOL

"NPG" Glycol
2,2-Dimethyl-1,3-Propanediol

$$HO-CH_2-\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}-CH_2-OH$$

Table 7.85: Physical Properties of Neopentyl Glycol *(41)*

Empirical Formula	$C_5H_{12}O_2$
Molecular Weight (calcd.)	104.15
Equivalent Weight (theor.)	52.08
Acid Number	0.01
Hydroxyl Number (average)	1075
Saponification Number	0.14
Acid, as acetic acid, wt. %	0.05 max.
Aldehyde, as hydroxypivaldehyde, wt. %	0.70 max.
Ester, as neopentyl hydroxypivaldehyde, wt.%	1.50 max.
Water, wt. %	1.00 max.
Appearance	White, crystalline solid
Autoignition Temp. (ASTM D286-30), °F.	750
,°C.	399
Boiling Range, °C., at 3.35 mm. Hg	93-94
25 mm. Hg	121-123
760 mm. Hg	210

Bulk Density, 21°C., g./cc.	1.06
lb./cu. ft.	66.4
Color, APHA, ppm., max.	25ᵃ
Critical Pressure, atm. (estd.)	36
Critical Temp., °K. (estd.)	653
Critical Volume, cu. ft./lb. (estd.)	0.059
cc./g. (estd.)	3.683
Crystal Density, 25°C., g./cc.	1.11
lb./cu. ft.	69.3
Crystallization Point, °C.	128 (same as m.p.)
Effect on Metals:	No corrosive effect on mild steel, galvanized steel or tinplate. Slightly corrosive to aluminum.
Fire Point (Cleveland Open Cup), °F.	305
°C.	151.6
Flash Point (Cleveland Open Cup), °F.	305
°C.	151.6

(continued)

Table 7.85: (continued)

Heat Capacity, Solid,	B.t.u./lb./°F. (estd.)	0.383
	cal., g./g./°C. (estd.)	0.383
Heat of Combustion,	B.t.u./lb. (estd.)	−12,917
	cal., g./g. (estd.)	−7,176
	B.t.u./lb. mole	−1,345,306
	cal., g./g. mole	−747,391
Heat of Fusion,	B.t.u./lb. (estd.)	90
	cal., g./g. (estd.)	50

[a]Molten

Solubility

Solvent	Solubility, g./100 g. of Solvent, at 5°C.	15°C.	60°C.
Water	173	181	400
Acetone	23	60	439
Benzene	0.6	12	199
Cyclohexane	0.0	<1	0.4
Hexane	0.5	—	1.8
Isobutyl alcohol	87.5	—	—
Methyl ethyl ketone	25	41	>309
Methyl isobutyl ketone	7.9	14	76
Toluene	0	<1	39
Trichloroethylene	0.2	<1	117

Specific Gravity, 25°/4°C. 1.066

PENTANEDIOLS

Table 7.86: Kinematic Viscosity of Aqueous Pentanediol Solutions at 20° and 40°C, in Centistokes *(32)*

1,2-Pentanediol			1,5-Pentanediol		
Glycol, %	Viscosity 20° C	40° C	Glycol, %	Viscosity 20° C	40° C
10.36	1.5475	0.9275	10.17	1.516	0.9210
19.97	2.264	1.258	20.09	2.246	1.277
30.18	2.88	1.538	30.42	3.300	1.795
40.13	4.06	2.08	39.82	4.735	2.331
50.02	5.73	2.82	50.04	7.08	3.350
59.96	8.02	3.742	60.12	11.30	5.250
69.97	13.03	5.725	70.45	20.9	8.842
79.85	19.85	8.138	80.20	36.22	14.46
90.05	38.20	13.62	89.75	66.25	25.70
100	68.55	20.82	100	115.65	43.58

Table 7.87: Refractive Indices of Aqueous Pentanediol Solutions at 20° and 40°C *(32)*

1,2-Pentanediol			1,5-Pentanediol		
Glycol, %	n_D^{20}	n_D^{40}	Glycol, %	n_D^{20}	n_D^{40}
10.36	1.3452	1.3430	10.17	1.3444	1.3420
19.97	1.3585		20.29		1.3543
20.64		1.3500	20.59	1.3572	
30.94	1.3705	1.3682	30.42	1.3700	1.3682
41.26	1.3830	1.3800	40.43	1.3833	1.3800
51.05	1.3930	1.3895	50.45	1.3960	1.3910
61.28	1.4050	1.3990	60.51	1.4080	1.4033
70.00	1.4120	1.4068	70.73	1.4198	1.4159
80.04	1.4223	1.4182	80.08	1.4304	1.4260
90.05	1.4320	1.4254	90.15	1.4417	1.4367
100	1.4390	1.4326	100	1.4500	1.4448

1,6-HEXANEDIOL

$CH_2OHCH_2CH_2CH_2CH_2CH_2OH$

Table 7.88: Physical Properties of 1,6-Hexanediol *(32)*

This glycol is very soluble in water.

Boiling point at 760 mm. Hg	243° C
Flash point, Cleveland open cup	265° F
Melting point	42° C
Molecular weight	118.17
Specific gravity (apparent)	0.958

2,5-HEXANEDIOL

$CH_3CHOHCH_2CH_2CHOHCH_3$

Table 7.89: Physical Properties of 2,5-Hexanediol *(32)*

This six-carbon glycol is the most viscous of the family. It is completely miscible with water.

Boiling point at 760 mm. Hg	220.8° C
Flash point, Cleveland open cup	220° F
Freezing point	Sets to a glass below -50° C
Molecular weight	118.17
Refractive index at 20° C, n_D	1.4474
Specific gravity (apparent) at 45/15.6° C	0.9617
Viscosity at 20° C	37 cp.

HEXYLENE GLYCOL

2-Methyl-2,4-Pentanediol
Methyl Amylene Glycol
Diacetone Glycol

$CH_3COH(CH_3)CH_2CHOHCH_3$

Table 7.90: Physical Properties and Specifications of Hexylene Glycol *(32)*

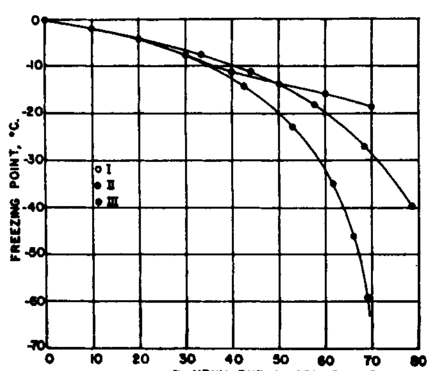
Acidity as acetic acid	0.005% by wt., max.
Boiling point at 760 mm. Hg	198.27° C 197.1° C
at 50 mm. Hg	125° C
at 10 mm. Hg	94° C
Color, Pt-Co (Hazen) standard	15, max.
Critical properties, P_c	499 psia
T_c	1221° R
V_c	6.78 ft./mole
Density (in air) at 760 mm. Hg	0.928 g./cc.
Density in air at any temp. may be obtained from equation:	D_t - 0.952 - 4.02 x 10^4 t
Density (in vacuo) at 0° C	0.9369 g./cc.
20° C	0.0216 g./cc.
30° C	0.9145 g./cc.
dt/dp at the boiling point	0.045° C/mm.
Flash point, Cleveland open cup	210° F 215° F
Freezing point	Becomes semisolid at -40° C without crystalline formation Sets to glass below -50° C
Distillation range (ASTM D-1078) (95% will distill between 196° C and 199° C)	195 to 200° C

(continued)

Table 7.90: (continued)

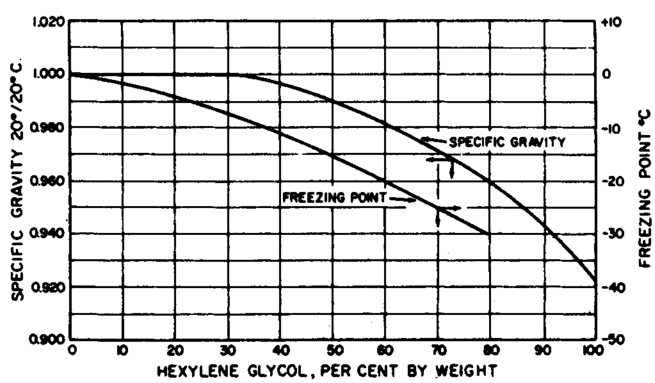
Latent heat of vaporization	12.3×13^3 cal./g.-mole 104.1 g.-cal./g. 208 Btu/lb.
Molecular weight	118.17
Pour point	-37.2° C (35° F)
Refractive dispersion, $(N_F - N_C) \times 10^4$	72.5
Refractive index, n_D^{20}	1.4276
n_D^{30}	1.4243
Specific gravity at 20/4° C 20/20° C	0.9216 0.9234
Δ Sp. Gr./Δ t, 0 to 55° C	0.00097
Surface tension, 20° C	33.1 dynes/cm.
Vapor pressure, 20° C	0.05 mm. Hg
Viscosity (absolute), 20° C	34.4 cp.
Water at 20° C	Miscible without turbidity with 19 vols. of n-heptane
Weight per gallon at 20° C	7.69 lb.

Table 7.91: Freezing Points of Hexylene Glycol-Water Mixtures *(32)*



Freezing Points of Hexylene Glycol (2-Methyl-2,4-pentanediol)-Water Mixtures. (I) Observed; (II) Theoretical, without hydration; (III) Theoretical, with complete hydration.

Table 7.92: Specific Gravity and Freezing Point of Hexylene Glycol-Water Mixtures *(14)*



PINACOL

Pinacone
2,3-Dimethyl-2,3-Butanediol
Tetramethylethylene Glycol

$HOC(CH_3)_2 \cdot C(CH_3)_2OH$

Table 7.93: Physical Properties of Pinacol *(32)*

Boiling point at 760 mm. Hg	174.4° C
Melting point	41.1° C
Molecular weight	118.17
The Hexahydrate	
Melting point	45.4° C
Specific gravity, d^{15}	0.967 (supercooled liquid)

2,2-DIETHYL-1,3-PROPANEDIOL

$HOCH_2C(C_2H_5)_2CH_2OH$

Table 7.94: Physical Properties of 2,2-Diethyl-1,3-Propanediol *(32)*

Boiling point at 10 mm. Hg	125° C
Freezing point	61.3° C
Molecular weight	132.20
Solubility in water at 20° C	25% by wt.
Specific gravity (apparent) at 20° C	1.052

2-ETHYL-1,3-HEXANEDIOL

Ethohexadial
Octanediol

$HOCH_2CH(C_2H_5)CHOHC_3H_7$

Table 7.95: Physical Properties of 2-Ethyl-1,3-Hexanediol *(32)*

Acidity as acetic acid	0.01% by wt., max.
Boiling point at 760 mm. Hg	243.1° C
Color, Pt-Co	15, max.
Distillation range	241 to 249° C
Flash point, open cup	265° F
Freezing point	Sets to glass below -40° C
Molecular weight	146.22
Refractive index, 20° C, n_D	1.4511
Solubility in water, 20° C	4.2% by wt.
Solubility of water in, 20° C	11.7% by wt.
Specific gravity, 20/20° C	0.9422
Suspended matter	Substantially free
Vapor pressure, 20° C	Less than 0.01 mm. Hg
Viscosity, 20° C	323 cp.
Weight per gallon (average), 20° C	7.83 lb.

2,5-DIMETHYL-3-HEXYNE-2,5-DIOL

Dimethyl Hexynediol

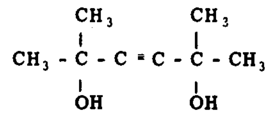
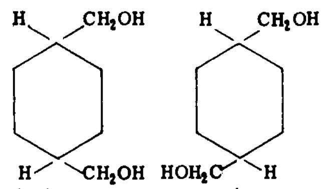


Table 7.96: Physical Properties of 2,5-Dimethyl-3-Hexyne-2,5-diol *(32)*

Boiling point	205-6° C
Freezing point	94-5° C
Surface tension at 25° C	
5% in water	41.2 dynes/cm.
0.1% in water	60.9 dynes/cm.
0.01% in water	66.9 dynes/cm.

1,4-CYCLOHEXANEDIMETHANOL



cis-isomer trans-isomer

Table 7.97: Properties of 1,4-Cyclohexanedimethanol

(approx. 70% trans-, 30% cis-isomers)

Empirical formula	$C_8H_{16}O_2$
Molecular weight (calcd.)	144.21
Equivalent weight	72.1
Crystallization point, °C.	35
Pour point, °C. (super-cooled)	10
Melting point, °C.	41-61
cis isomer	43
trans isomer	70
Boiling point, °C.	
760 mm.	285
100 mm.	216
10 mm.	160
1 mm.	118
cis isomer	288
trans isomer	284

Specific gravity	
Liquid:	
25°/4°C. (super-cooled)	1.026
50°/4°C. (super-cooled)	1.010
100°/4°C. (molten)	0.978
150°/4°C.	0.946
200°/4°C.	0.914
Solid:	
27°/4°C.	1.069
Density	
Liquid, lb./gal.:	
70°F. (super-cooled)	8.59
100°F. (super-cooled)	8.49
200°F.	8.20
300°F.	7.90
400°F.	7.60
Solid, 70°F., lb./cu. ft.	66.74

(continued)

Table 7.97: (continued)

Acid number	<0.03
Hydroxyl number	22.89
Saponification number	0.91
Refractive index, $n_D^{20°}$ (super-cooled)	1.4893
Flash point, Cleveland Open Cup, °F.	165
Fire point, Cleveland Open Cup, °F.	255
Solubility, 25°C., wt. %	
in water	miscible
water in	miscible
in methanol	miscible
in ethanol	miscible
in diethyl ether	2.5
in VM & P naphtha	<1
in benzene	<1
in acetone	56.4

Heat capacity, (estd.)

Liquid:	Temp., °C.	C_v, B.t.u./lb. °F.	C_p, B.t.u./lb. °F.
	50	0.505	0.648
	100	0.553	0.716
	150	0.609	0.794
	200	0.669	0.877

Solid: C_p, B.t.u./lb. °F. (estd.) 0.410

Thermal Conductivity (estd.)

Vapor:	Temp., °C.	k, B.t.u./hr. ft. °F.
	50	0.00602
	100	0.00772
	150	0.00960
	200	0.01229

Liquid:	Temp., °C.	k, B.t.u./hr. ft. °F.
	50	0.1118
	100	0.1229
	150	0.1280
	200	0.1311

Critical temperature, T_c, °C. (estd.)	
cis isomer	457
trans isomer	451
Critical pressure, P_c, atm. (estd.)	34.85
Critical volume, V_c, cu. ft./lb. (estd.)	0.0506

Viscosity:	Temp., °F.	cs.	S.U.S.
	75	1421.6	6568
	100	478.1	2209
	125	183.4	847

p-XYLYLENE GLYCOL

ω,ω'-Dihydroxy-p-Xylene

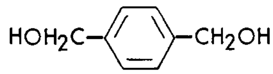


Table 7.98: Physical Properties of p-Xylylene Glycol *(32)*

Chlorine (total)	0.6% max.
Flash point (Cleveland open cup)	370° F
Molecular weight	138.16
Purity	95% min.
Set point	115-117.6° C
Specific gravity at 117° C	1.100
Toluene insolubles	0.5% max.

2-ETHYL-2-BUTYL-1,3-PROPANEDIOL

$HOCH_2C(C_2H_5)(C_4H_9)CH_2OH$

Table 7.99: Physical Properties of 2-Ethyl-2-Butyl-1,3-Propanediol *(32)*

Boiling point at 100 mm. Hg	195° C
Melting point	41.4° C
Molecular weight	160.25
Solubility in water at 20° C	0.8% by wt.
Specific gravity (apparent) at 50/20° C	0.931

3,6-DIMETHYL-4-OCTYNE-3,6-DIOL

Dimethyl Octynediol

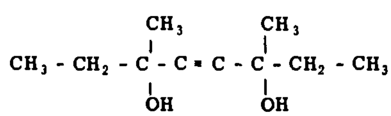


Table 7.100: Physical Properties of 3,6-Dimethyl-4-Octyne-3,6-diol *(32)*

Boiling point at 20 mm. Hg	135° C
Freezing point	55.6° C
Surface tension at 25° C	
5% in water	30.7 dynes/cm.
0.1% in water	55.3 dynes/cm.
0.01% in water	63.9 dynes/cm.

THIODIGLYCOL

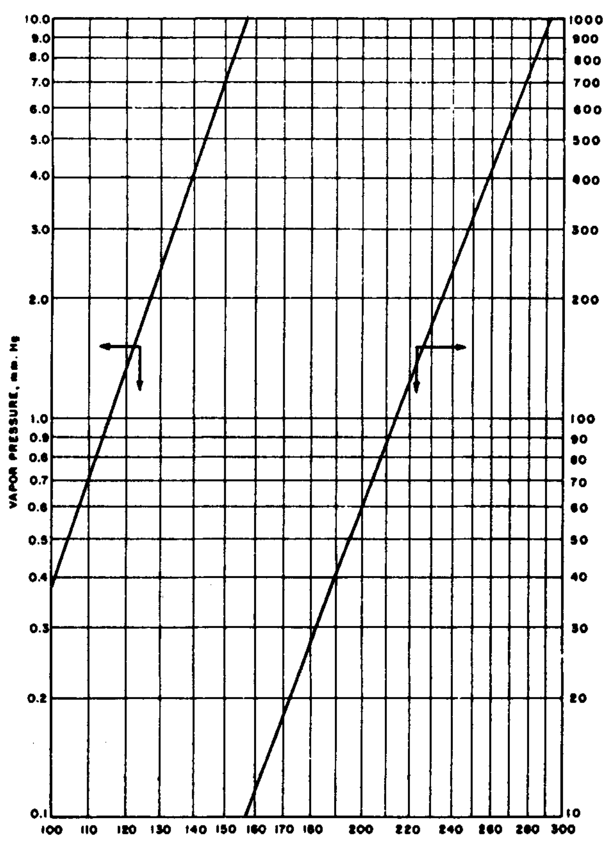
Thiodiethylene Glycol
β, β'-Dihydroxyethyl Sulfide

$HOCH_2CH_2{-}S{-}CH_2CH_2OH$

Table 7.101: Physical Properties of Thiodiglycol *(32)*

Acidity	1.0 mg. KOH/g. sample, max.	Heat of vaporization at 1 atm.	235 Btu/lb.
Boiling point at 760 mm. Hg 50 mm. Hg	283° C 194° C	Molecular weight	122.19
Δ Boiling point/Δ p	0.055° C/mm. Hg	Refractive index at 20° C n_D	1.5217
Color (Pt-Co)	200 max.	Specific gravity	1.1847
Coefficient of expansion at 55° C	0.00061/° C	Δ Sp. Gr./Δ t	0.00072
Flash point (open cup)	320° F	Vapor pressure at 20° C	Less than 0.01 mm. Hg
Freezing point	-10° C	Viscosity at 20° C	65.2 cp.
		Weight per gallin at 20° C at 15.56° C	9.85 lb. 9.88 lb.

Table 7.102: Vapor Pressure of Thiodiglycol at Various Temperatures *(19)*



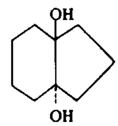
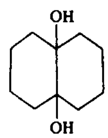
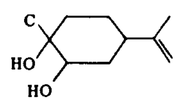
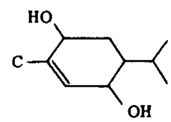
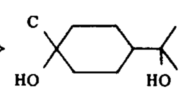
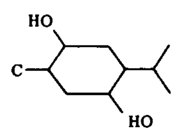
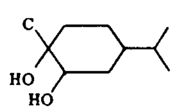
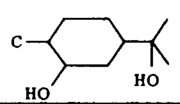
MISCELLANEOUS GLYCOLS

Table 7.103: Hydrates of Aliphatic Glycols *(32)*

Glycol				Hydrate	
Number of C Atoms	Name	Skeletal Structural Formula	M.p. (°C)	M.p. (°C)	n in $R(OH)_2 \times nH_2O$
2	Ethylene glycol	HO-C-C-OH	-12.9	-49.6 (cong.)	2
2	Ethylene glycol	HO-C-C-OH	-12.9	-40.7	0.67
4	meso-2,3-Butanediol	HO OH C-C-C-C	34.4	16.8	6(5)†
4	±2,3-Butanediol	HO OH C-C-C-C	7.6	---	0
5	2-Methyl-2,3-butanediol	HO OH C-C-C-C C	liq.	23.5-4	6
6	Pinacol	HO OH C-C-C-C C C	41.4	41.25	1
6	Pinacol	HO OH C-C-C-C C C	41.4	46.5	6
8	2,5-Dimethyl-2,5-hexanediol	HO OH C-C-C-C-C-C C C	92	41-2	6
9	2,6-Dimethyl-2,6-heptanediol	HO OH C-C-C-C-C-C-C C C	76-77	60-61	1
10	2,7-Dimethyl-2,7-octanediol	HO OH C-C-C-C-C-C-C-C C C	92	59	2
13	2,10-Dimethyl-2,10-undecanediol	HO OH C-C-CCCCCCC-C-C C C	81	---	?
14	2,11-Dimethyl-2,11-dodecanediol	HO OH C-C-CCCCCCCC-C-C C C	67.5	---	?

†$5H_2O$ (50% H_2O) has been assigned. The maximum of the very flat freezing point curve has been found at 55% H_2O, no formula being assigned. This composition agrees excellently with $6H_2O$ which requires 54.5% H_2O.

Table 7.104: Hydrates of Cyclic Glycols *(32)*

Glycol				Hydrate	
Number of C Atoms	Name	Skeletal Structural Formula	M.p. (°C)	M.p. (°C)	n in $R(OH)_2 \times nH_2O$
9	trans-Octa-hydroindan-8,9-diol		73-4	---	0.5 to 1.0
10	trans-Decahydro-naphthalene-9,10-diol		96	80-5	1.0?
10	cis-Decahydro-naphthalene-9,10-ciol		89.5	---	Unknown
10	trans-p-Menth-8 (9) -ene-1,2-diol		73	60	3
10	cis-p-Menth-8 (9) -ene-1,2-diol		71-2	---	0
10	cis(?)-p-Menth-1 (2) -ene-3,6-diol		53-4	27	3?
10	cis-Terpin†		105	121	1
10	trans-Terpin‡		156-8	---	0
10	p-Menthane-2,5-diol		88-9	58-9	3
10	p-Menthane-1,2-diol		89	52	3 & 1
10	p-Menthane-2,8-diol (neoiso-dihydrocarveol hydrate)		93-4	65-75	Unknown

†Subject of crystallographic studies.
‡Stelzner's Literatur Register 1919-21 reports the formation of a hydrate and cites O. Aschan, "Bidrag till kännedon af Finlands natur ochfolk," 77, No. 1 (1918). The report appears to be without foundation.

(continued)

Table 7.104: (continued)

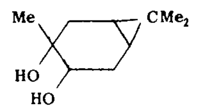
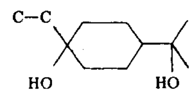
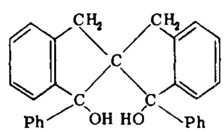
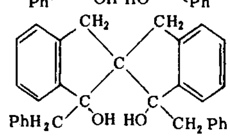
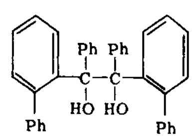
	Glycol			Hydrate	
Number of C Atoms	Name	Skeletal Structural Formula	M.p. (°C)	M.p. (°C)	n in $R(OH)_2 \times nH_2O$
10	(+)-Carene-β-glycol or 3,4-Carane-diol (trans-2,3-dihydroxy-3,7,7-trimethyl-bicyclo-0,1,4-heptane)		90-91	75	1
11	Homoterpin		75-6	---	1
14	iso (±)-Hydrobenzoin	PhCHOHCHOHPh	121	96	Unknown
20	Dihydrodicarveol	$C_{20}H_{26}O_2$	166	100	2
29	3,3'-Dihydroxy-3,3'-diphenyl-2,2'-spiro-biindan		164	125-30	1 & 3
31	3,3'-Dihydroxy-3,3'-dibenzyl-2,2'-spiro-biindan		169	134	3
38	α-s-2,2'-Diphenylbenzopinacol		175	---	1
38	β-s-2,2'-Diphenyl-benzopinacol		152-8	---	1

Table 7.105: Freezing Points of Aqueous Ethylene Glycol and Propylene Glycol Solutions *(42)*

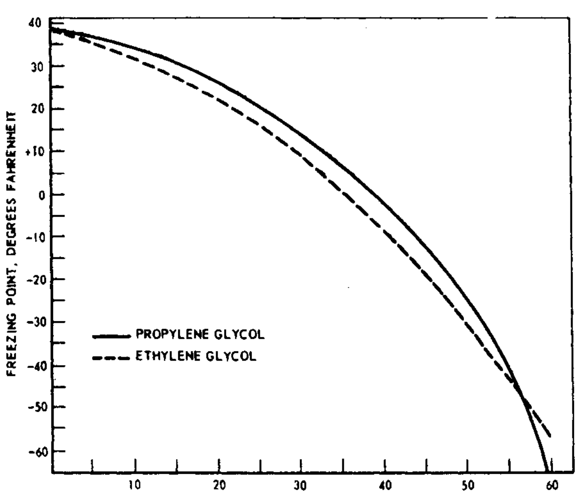


Table 7.106: Freezing Points of Various Aqueous Glycol Solutions, °C *(32)*

Glycol, %	1,2-Propanediol	1,3-Propanediol	1,2-Butanediol	1,3-Butanediol	levo-2,3-Butanediol	1,4-Butanediol	1,2-Pentanediol	1,5-Pentanediol
10	-3.12	-2.86	-2.60	-2.34	-3.1	-2.30	-2.3	-2.3
20	-7.6	-6.5	-6.0	-5.2	-7.1	-5.48	-4.8	-4.9
30	-14.0	-11.8	-11.0	-10.5	-12.4	-10.0	-6.8	-8.4
40	-22.7	-18.8	-16.5	-16.8	-19.4	-14.8	-8.4	-11.3
50	-34.5	-27.7	-22.4	-25.2	-29.6	-22.0	-10.2	-15.3
60	-48.2	-40.0	-29.0	-35.3	-40.4	-31.3	-12.6	-21.0

Table 7.107: Freezing Points of Various Aqueous Alcohols, Glycols and Glycerol *(32)*

Solute by Weight, %	Methanol		Ethanol		Ethylene Glycol		Glycerol		levo-2,3-Butanediol	
	F.p. Observed, °C	F.p. Calculated, °C	F.p. Observed, °C	F.p. Calculated, °C	F.p. Observed, °C	F.p. Calculated, °C	F.p. Observed, °C	F.p. Calculated, °C	F.p. Observed, °C	F.p. Calculated, °C
10	-6.3	-6.46	-4.5	-4.49	-3.6	-3.33	-2.0	-2.25	-3.1	-2.30
20	-15.3	-14.5	-10.5	-10.1	-8.3	-8.27	-5.2	-5.05	-7.1	-5.17
30	-26.3	-24.9	-20.0	-17.3	-14.7	-12.9	-9.9	-8.67	-12.4	-8.85
40	-39.7	-38.8	-29.4	-27.0	-23.5	-20.0	-15.9	-12.0	-19.4	-14.3
50	-55.2	-58.1	-37.0	-40.4	-35.0	-30.0	-24.6	-20.2	-29.6	-20.7
60			-43.8	-60.7	-50	-45.0	-37.9	-30.3	-40.4	-31.0

Table 7.108: Compatibility of Coupling Solvents with Carbon Tetrachloride and Water *(14)*

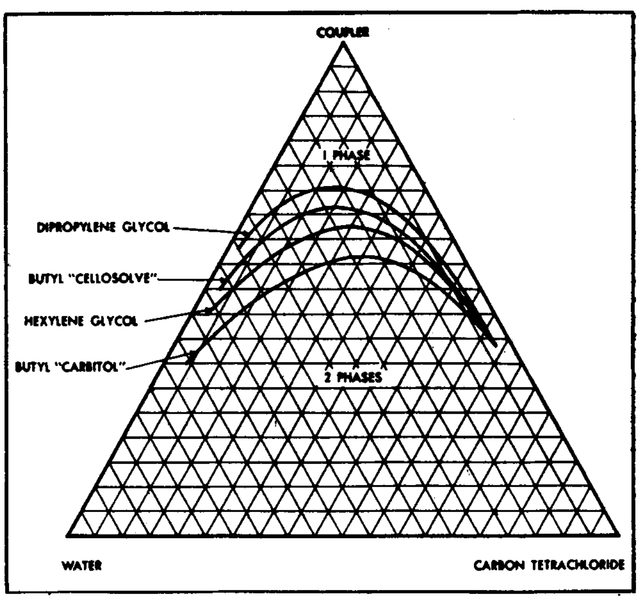
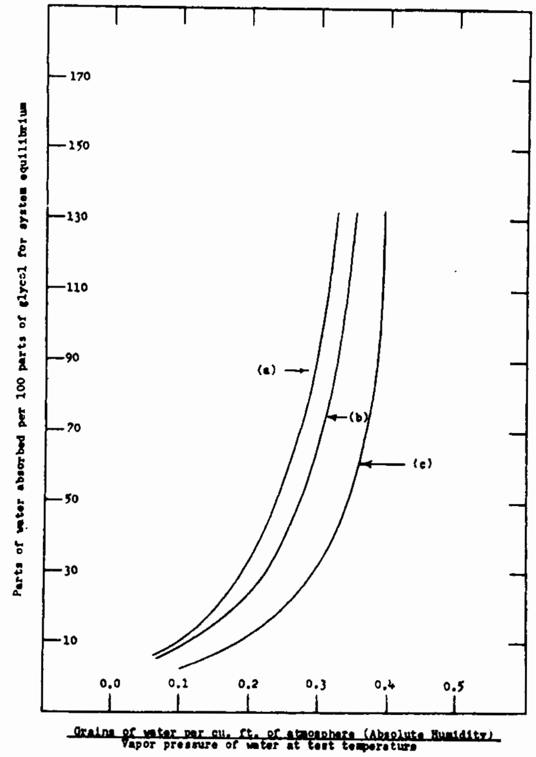


Table 7.109: Key Hygroscopicity Curve *(55)*



Key hygroscopicity curves for the various glycols: (a) ethylene glycol; (b) diethylene glycol; and (c) dipropylene glycol.

Table 7.110: Surface Tension of Glycol-Water Systems *(14)*

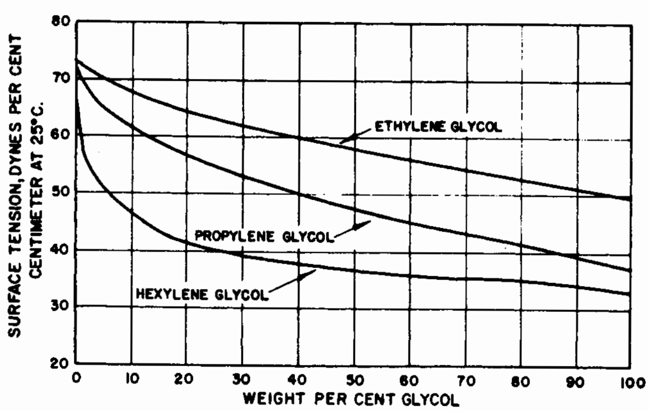


Table 7.111: Vapor Pressure of Glycols *(14)*

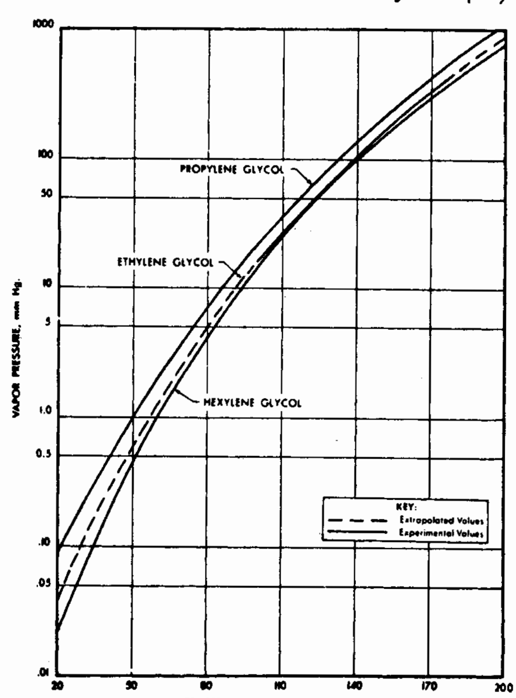


Table 7.112: Viscosity of Glycols *(32)*

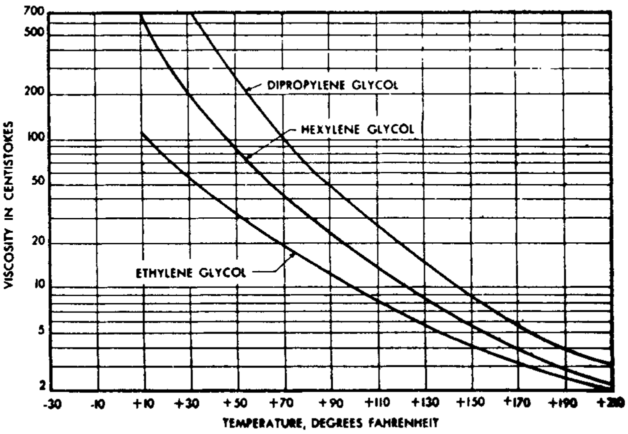


Table 7.113: Water Absorption by Glycols as a Function of Time *(14)*

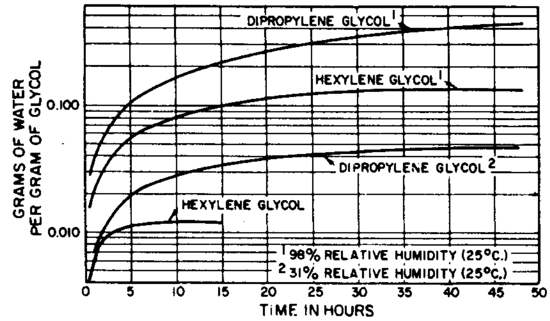


Table 7.114: Water Absorption by Glycols as a Function of Relative Humidity *(14)*

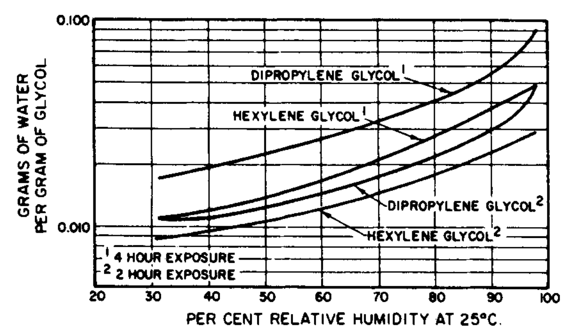


Table 7.115: Refractive Index, Specific Gravity, and Boiling Point Measurements of Various Glycols *(32)*

Compound	Refractive Index	Specific Gravity, d^t_4	Boiling Point, °C., 760 mm.
1,2-Propanediol	25°C. 1.4316 (17) 1.4313† 20°C. 1.4331 (14) 1.4324†	23°C. 1.0354 (17) 20°C. 1.0364 (14) 1.0361†	187 (17) 186†
1,3-Propanediol	25°C. 1.4385 (17) 1.4380† 21°C. 1.4394 (17) 20°C. 1.4389†	20°C. 1.0538 (17) 1.0529†	215 (17) 213.5†
1,2-Butanediol	20°C. 1.4378†	20°C. 1.0024†	190.5†
1,3-Butanediol	25°C. 1.4410 (17) 1.4391 (12) 1.4388† 20°C. 1.4404 (2) 1.4398†	20°C. 1.0053 (17) 1.0035 (12) 1.002 (2) 1.0037†	207.5 (17) 208 (2) 207†
1,4-Butanediol	20°C. 1.4467 (10) 1.4459 (2) 1.4460†	20°C. 1.0171 (10) 1.0160 (2) 1.0185†	230 (2) 228†
1,2-Pentanediol	24°C. 1.4390 (16) 25°C. 1.4380† 20°C. 1.4390†	24°C. 0.9691 (16) 20°C. 0.9723†	210 (16) 206†
1,5-Pentanediol	26°C. 1.4480 (16) 25°C. 1.4484† 20°C. 1.4500†	26°C. 0.9890 20°C. 0.9914†	239 (16) 238†

†Authors' observations.
§As cited in the fifth and earlier editions of Getman and Daniels' Outlines of Physical Chemistry, John Wiley and Sons Inc., New York, 1931.

Table 7.116: Relative Solvent Properties of Glycols *(23)*

S = Completely Soluble I = Insoluble < = Less Than > = Greater Than	Ethylene Glycol	Diethylene Glycol	Triethylene Glycol	Tetraethylene Glycol	Propylene Glycol	Dipropylene Glycol	Tripropylene Glycol
Benzene	5.7	31.3	S	S	19.2	S	S
Carbon Tetrachloride[1]	6.2	26.2	33.6	62	23.4	S	S
Dibutyl Phthalate	0.5	10.6	16.5	S	8.1	S	S
Dichloroethyl Ether[1]	10.6	S	S	S	37.1	S	S
Diethanolamine[1]	S	S	S	S	S	S	S
DOWANOL* PM Glycol Ether[1]	S	S	S	S	S	S	S
DOWANOL* DPM Glycol Ether[1]	S	S	S	S	S	S	S
Ethyl Alcohol	S	S	S	S	S	S	S
Ethyl Ether	8.2	16.3	16.9	20	S	S	S
Methyl Alcohol	S	S	S	S	S	S	S
Methyl Isobutyl Carbinol	S	S	S	S	S	S	S
Methyl Isobutyl Ketone	12	S	S	S	S	S	S
Monochlorobenzene[1]	5.7	S	S	S	22.5	S	S
Monoethanolamine[1]	S	S	S	S	S	S	S
ortho-Dichlorobenzene[1]	4.5	48.4	S	S	19.4	S	S
Perchloroethylene[1]	0.7	10.7	15.0	19.0	14.5	S	S
Phenol[1]	S	S	S	S	S	S	S
Styrene[1]	3.4	36	S	S	15	S	S
Toluene	2.9	17.2	24.8	89	12.3	S	S
Urea	48	30	37	28	29	12	10
Castor Oil	1	<0.5	<0.5	<1	0.8	S	S
Coconut Oil	1	1	1	<1	1	1	3
Cottonseed Oil	1	1	1	<1	1	1	<1
Hydrous Wool Fat	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Lard Oil	1	1	1	<1	1	1	<1
Linseed Oil	1	1	1	<1	1	1.4	2.5
Oiticica Oil	<1	<1	<1	<1	<1	<1	<1
Olive Oil	1	1	1	<1	1	0.7	1.5
Pine Oil	S	S	S	S	S	S	S
Soya Bean Oil	1	1	1	<1	1	1	<1
Sperm Oil	1	1	1	<1	1	1	<1
Tall Oil	<1	<1	<1	<1	<1	S	S
Tung Oil	1	1	1	<1	1	1	<1
Turkey Red Oil	<1	<1[2]	1[2]	1[2]	<1[2]	3[2]	4[2]
Paraffin Oil	1	1	1	<1	1	1	<1
SAE No. 10 Oil	1	1	1	<1	1	1	<1
VMP Naphtha	<1	<1	<1	1	1	10	14
Animal Glue (Dry)	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Dextrin	<1	<1	<1	<1	<1	<1	<1
Gum Damar	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Kauri Gum	<0.5	<0.5	<0.5	>16[3]	<5	<5	>16[3]
Sudan III	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Shellac	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1

[1]Product of The Dow Chemical Company
[2]Forms stable emulsion from this concentration to 100%.
[3]Becomes too viscous to stir beyond 16%.
*Trademark of The Dow Chemical Company

Table 7.117: Effect of Various Glycols on Synthetic Rubber Samples—Results Reported as % Volume and % Weight Increase *(23)*

Glycol	GN-427T1		GRS-53115T		FA-Thiokol		Gum Rubber	
	% Vol	% Wt	% Vol	% Wt	% Vol	% Wt	% Vol	% Wt
				3 Days Immersion				
Ethylene	−.2	−.2	−.1	−.5	.5	.2	.2	.2
Diethylene	−.12	−.2	−.1	−.5	.3	.0	.1	.0
Triethylene	−.1	−.1	−.1	−.5	.5	.1	.3	.1
Propylene	−.2	−.2	.1	−.3	.3	.0	.2	.0
Dipropylene	−.1	−.2	.0	−.5	.3	−.1	.1	.1
				10 Days Immersion				
Ethylene	−.2	−.2	−.3	−.7	.3	.2	.3	.5
Diethylene	−.3	−.3	−.2	−.8	.3	.0	−.2	.0
Triethylene	.0	−.1	−.1	−.6	.6	.3	.0	.1
Propylene	−.1	−.1	−.3	−.7	.0	−.1	−.1	.0
Dipropylene	.1	−.2	−.1	−.6	.1	−.2	.0	.1

Table 7.118: Solubility of Cellulose Derivatives in Glycols *(23)*

Glycol	50 CPS. ST. E/C	½ Second Cellulose Nitrate	Cellulose Acetate FM 3
Ethylene	Insoluble	Swelled	Insoluble
Diethylene	Insoluble	>20% Soluble	Insoluble
Triethylene	Insoluble	>20% Soluble	Insoluble
Propylene	Insoluble	Swelled	Insoluble
Dipropylene	Insoluble	>20% Soluble	Insoluble

Table 7.119: Compatibility of Film Cast from 80/20 Toluene/Alcohol *(23)*

Glycol	50 CPS. ST. E/C			½ Second Cellulose Nitrate			Cellulose Acetate FM 3		
	Clear	Haze	Opaque	Clear	Haze	Opaque	Clear	Haze	Opaque
Ethylene	1%	3%	10%	3%	5%	10%	>10	20	–
Diethylene	1%	3%	10%	1%	5%	10%	>20	30	–
Triethylene	–	1%	3%	1%	3%	15%	>20	30	–
Propylene	1%	3%	10%	1%	3%	10%	>10	20	–
Dipropylene	20%	25%	30%	>50%	–	–	>40	50	–

Note: Table shows % glycol in film with the properties shown.

Table 7.120: Relative Humectant Values *(23)*

Temperature of Air °F	Glycol	Relative Humidities 10%	20%	30%	40%	50%	60%	70%	80%	90%
	Ethylene	97.5	93.4	89.3	85.7	82	78	72	63	48
	Diethylene	97.8	95.1	92.0	89.0	86	83	78	68	52
20	Triethylene	98.5	96.8	94.0	91.1	89	83	78	66	51
(−6.7°C)	Propylene	96.8	91.4	90.0	84.6	77	73	68	55	40
	Dipropylene	98.5	97.0	95.1	92.6	89	85	79	67	51
	Ethylene	97.3	93.2	89.1	85.4	82	76	69	60	42
	Diethylene	97.7	95.0	92.0	89.0	86	82	77	67	50
40	Triethylene	98.4	96.5	93.8	91.0	88	83	77	65	51
(4.4°C)	Propylene	97.0	92.3	90.2	85.2	78	74	68	55	40
	Dipropylene	98.4	96.9	95.0	92.5	89	85	79	67	51
	Ethylene	97.1	93.0	88.9	85.0	81	75	66	57	37
	Diethylene	97.7	95.0	92.0	89.0	86	82	76	68	48
60	Triethylene	98.2	96.2	93.6	90.8	86	82	77	65	50
(15.6°C)	Propylene	97.1	92.9	90.4	85.8	80	74	68	55	40
	Dipropylene	98.4	96.8	94.8	92.4	89	85	79	67	51
	Ethylene	96.8	92.8	88.6	84.7	80	73	84	55	36
	Diethylene	97.6	94.9	92.0	89.0	85	81	75	65	47
60	Triethylene	98.1	96.0	93.4	90.7	85	82	76	64	50
(26.7°C)	Propylene	97.1	93.5	90.5	86.3	81	75	68	55	40
	Dipropylene	98.3	96.7	94.7	92.3	89	85	79	67	51
	Ethylene	96.6	92.7	88.4	84.3	79	72	83	53	35
	Diethylene	97.6	94.8	92.0	89.0	85	81	74	64	48
100	Triethylene	98.0	95.7	93.2	90.6	84	82	76	64	49
(37.8°C)	Propylene	97.2	93.9	90.6	86.6	82	75	88	55	40
	Dipropylene	98.3	96.6	94.6	92.1	89	85	79	67	51
	Ethylene	96.4	92.5	88.2	84.0	78	71	62	51	34
	Diethylene	97.6	94.8	92.0	89.0	85	60	73	83	45
120	Triethylene	97.8	95.4	93.0	90.5	83	82	75	63	49
(48.9°C)	Propylene	97.2	94.3	90.7	86.7	83	78	66	55	40
	Dipropylene	98.2	96.5	94.5	92.0	89	85	79	67	51

Note: Values are given as the percent by weight of glycol in water solution required to maintain equilibrium in contact with air of various temperatures and humidities.

Table 7.121: Water Vapor Dew Points Over Aqueous Ethylene Glycol Solutions *(23)*

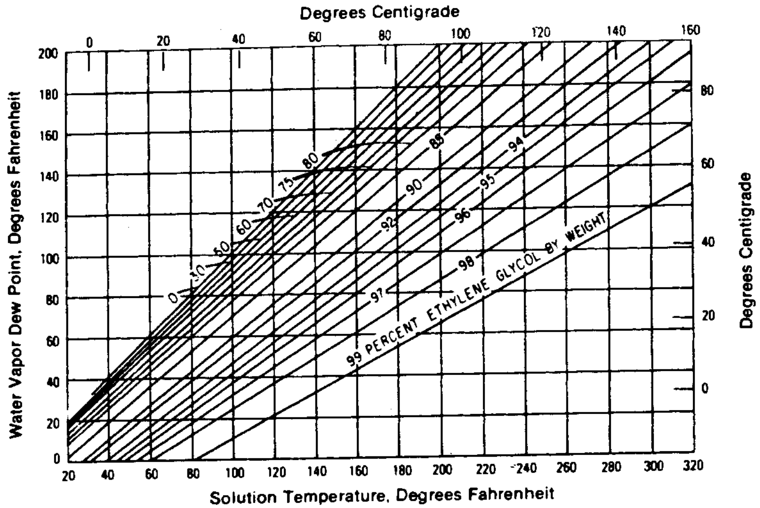


Table 7.122: Water Vapor Dew Points Over Aqueous Diethylene Glycol Solutions *(23)*

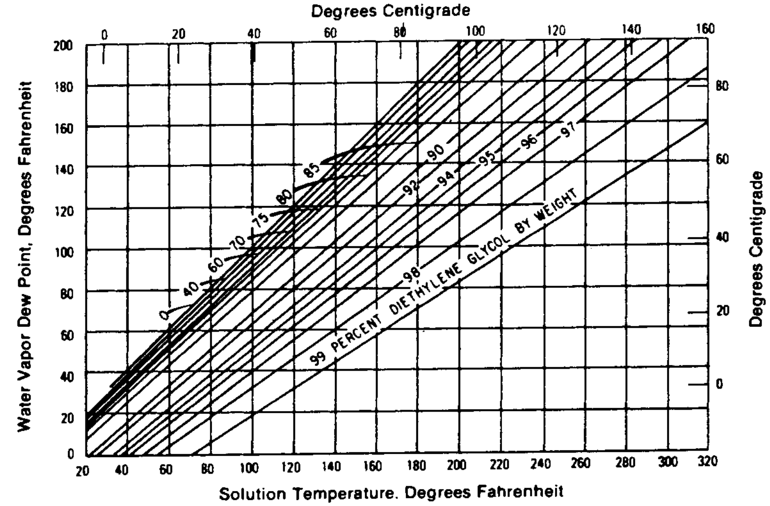


Table 7.123: Water Vapor Dew Points Over Aqueous Triethylene Glycol Solutions *(23)*

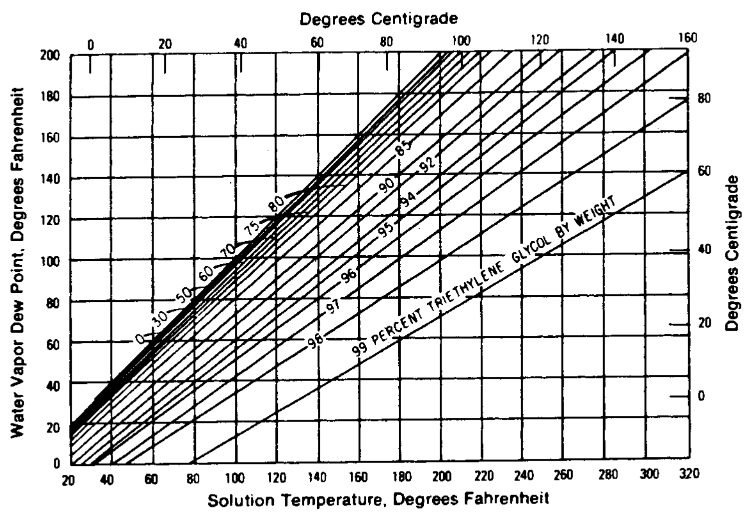


Table 7.124: Water Vapor Dew Points Over Aqueous Propylene Glycol Solutions *(23)*

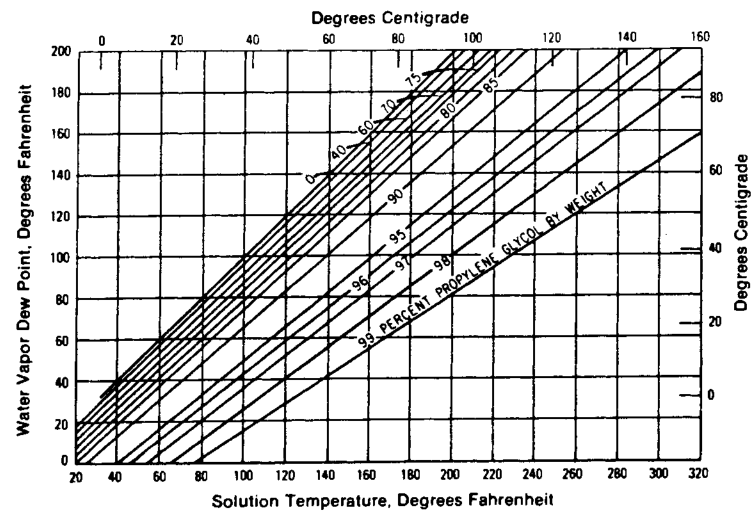


Table 7.125: Water Vapor Dew Points Over Aqueous Dipropylene Glycol Solutions *(23)*

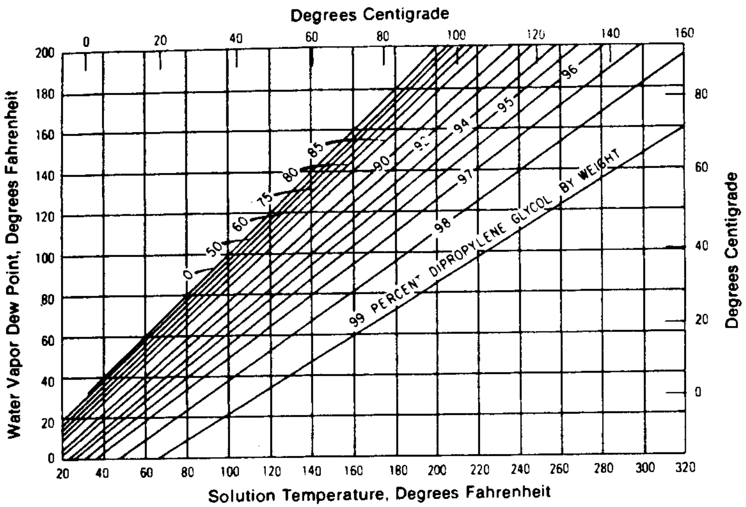


Table 7.126: Boiling Points of Glycols at 50 mm Hg *(23)*

Water	100°F (37.8°C)
Ethylene Glycol	258°F (125.5°C)
Diethylene Glycol	338°F (170°C)
Triethylene Glycol	387°F (197.2°C)
Tetraethylene Glycol	453°F (233.9°C)
Propylene Glycol	240°F (115.6°C)
Dipropylene Glycol	307°F (152.8°C)
Tripropylene Glycol	356°F (180°C)

Table 7.127: Total Pressure Over Aqueous Ethylene Glycol Solutions vs Temperature *(23)*

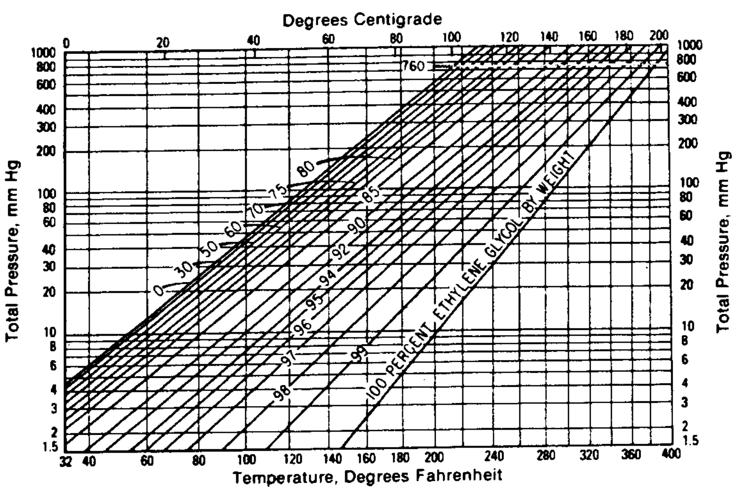


Table 7.128: Total Pressure Over Aqueous Diethylene Glycol Solutions vs Temperature *(23)*

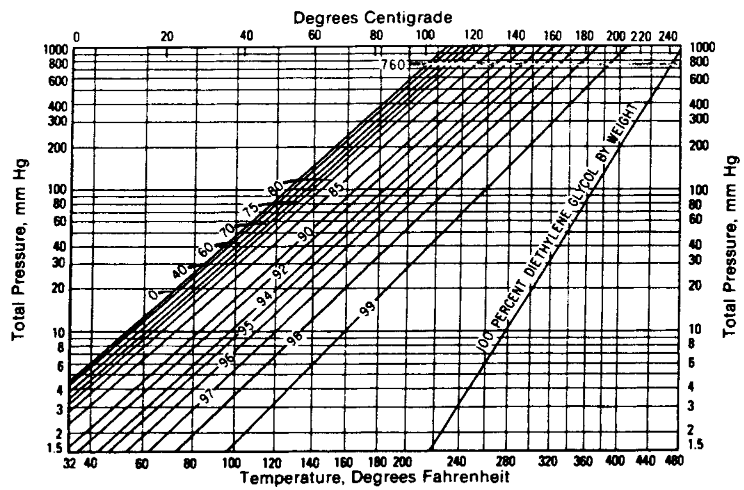


Table 7.129: Total Pressure Over Aqueous Triethylene Glycol Solutions vs Temperature *(23)*

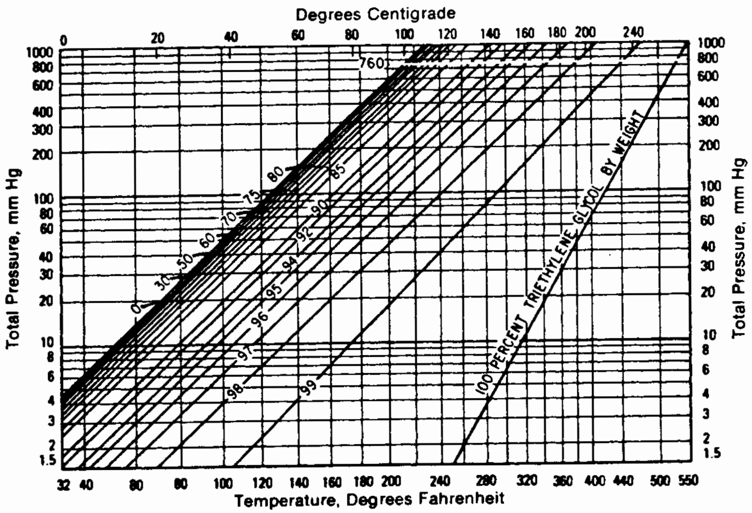


Table 7.130: Total Pressure Over Aqueous Propylene Glycol Solutions vs Temperature *(23)*

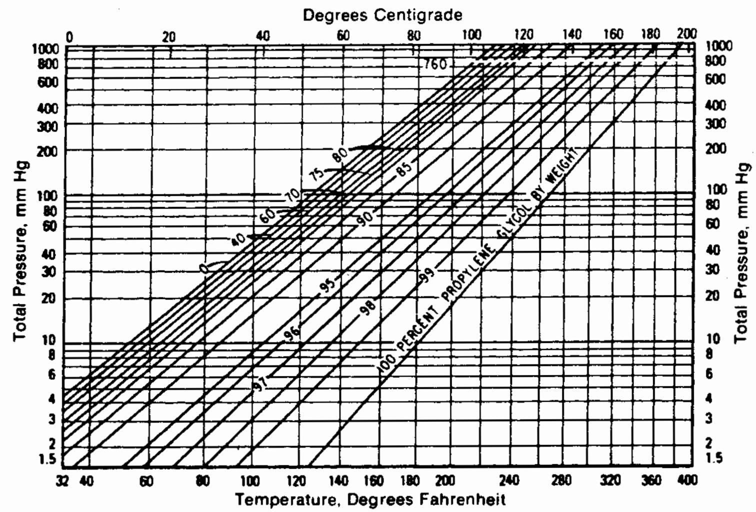


Table 7.131: Total Pressure Over Aqueous Dipropylene Glycol Solutions vs Temperature *(23)*

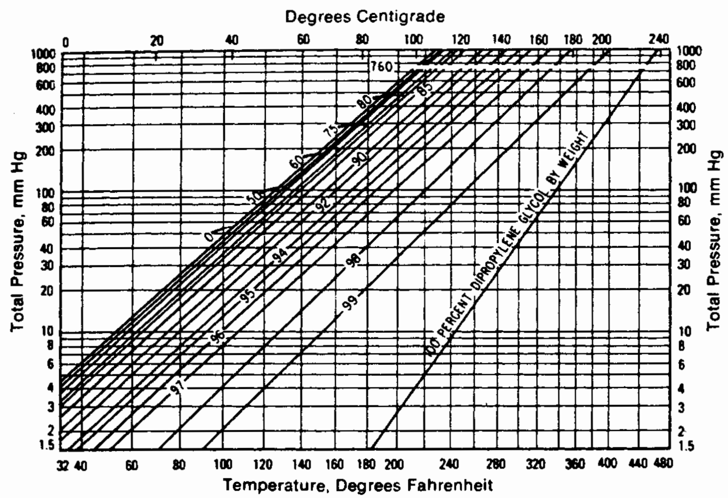


Table 7.132: Vapor-Liquid Composition Curves for Aqueous Ethylene Glycol Solutions *(23)*

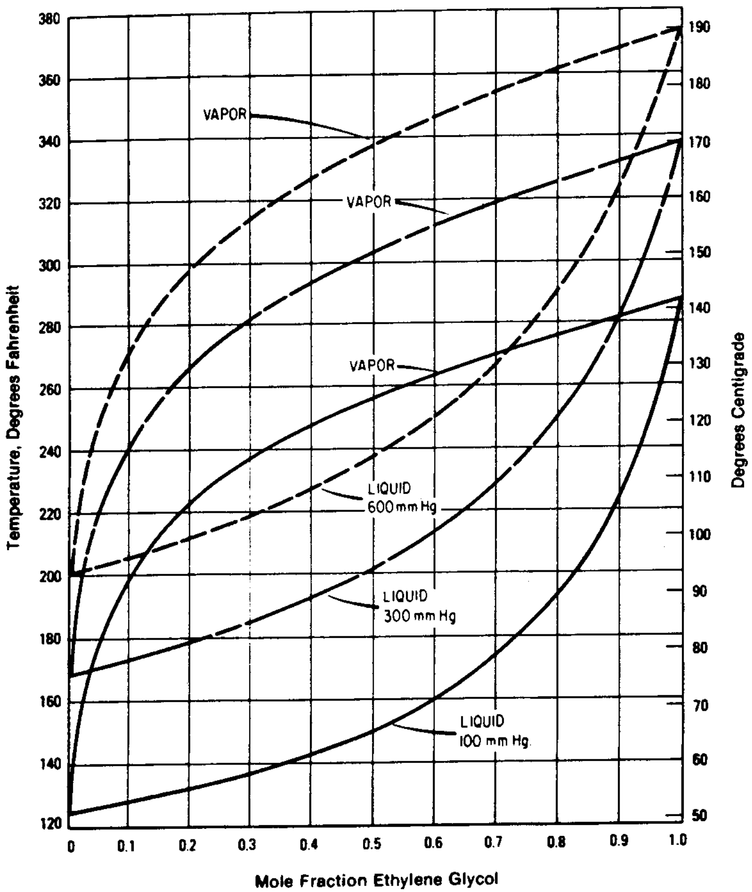


Table 7.133: Vapor-Liquid Composition Curves for Aqueous Diethylene Glycol Solutions *(23)*

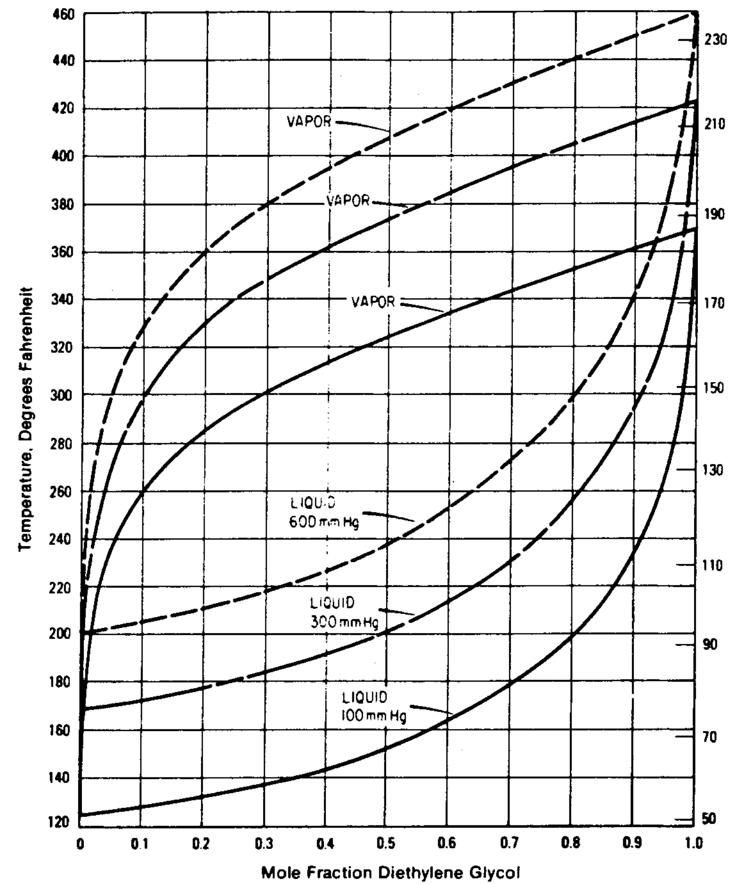


Table 7.134: Vapor-Liquid Composition Curves for Aqueous Triethylene Glycol Solutions *(23)*

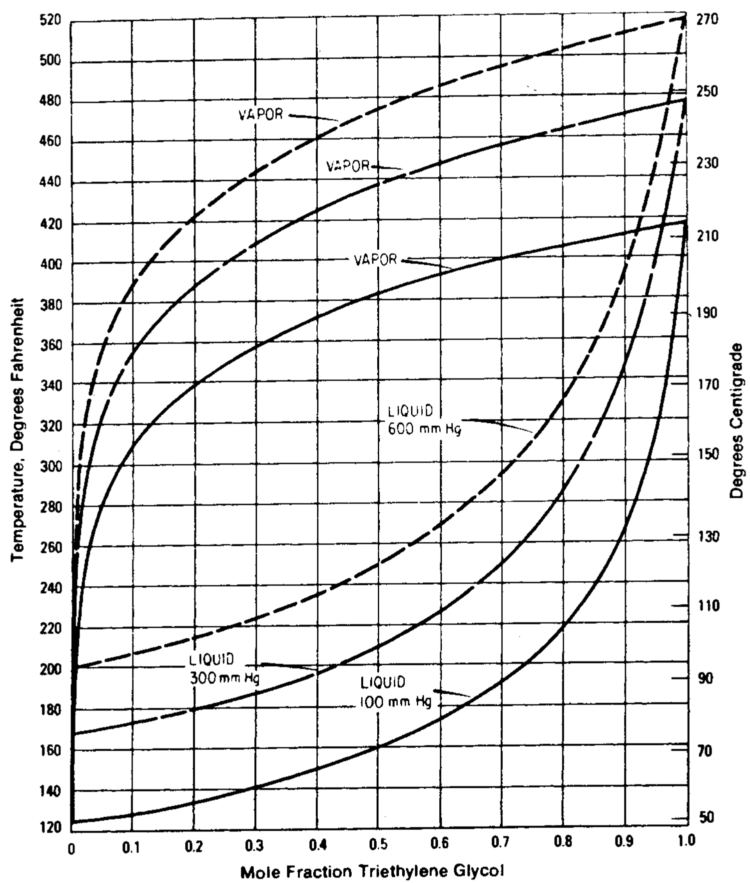


Table 7.135: Vapor-Liquid Composition Curves for Aqueous Propylene Glycol Solutions *(23)*

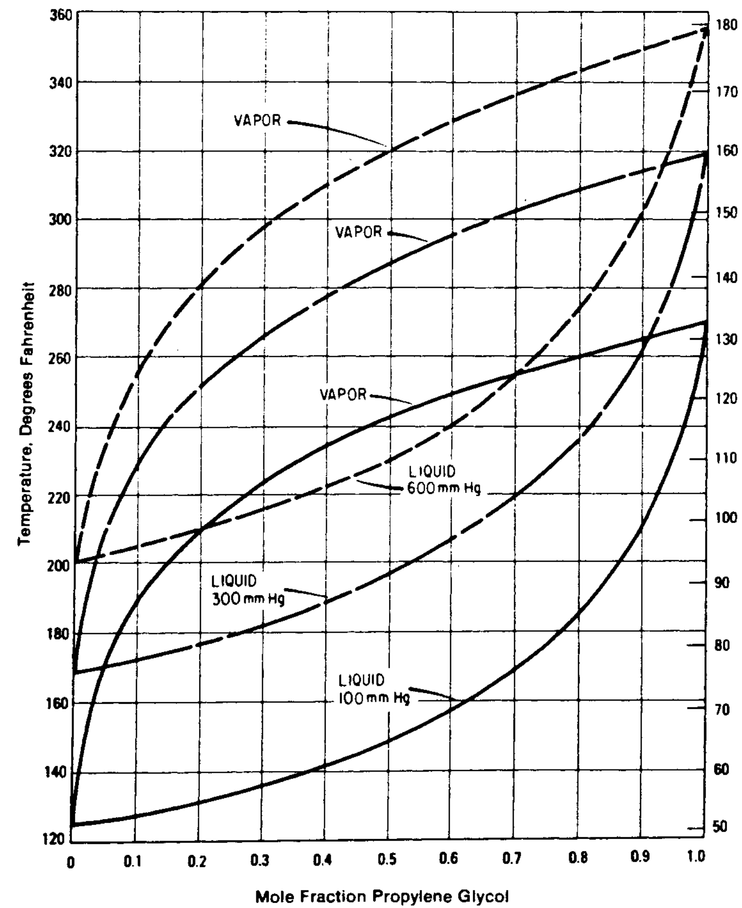


Table 7.136: Vapor-Liquid Composition Curves for Aqueous Dipropylene Glycol Solutions *(23)*

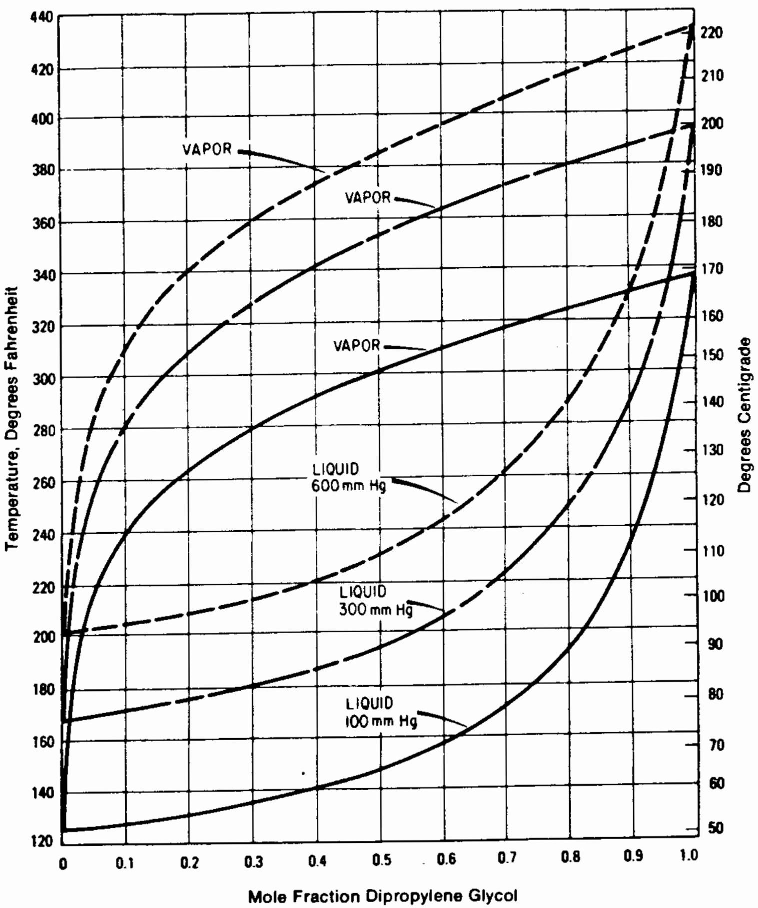


Table 7.137: Pour Points of Glycols *(23)*

Ethylene Glycol	<−75°F (−59°C)
Diethylene Glycol	−65°F (−54°C)
Triethylene Glycol	−73°F (−58°C)
Tetraethylene Glycol ..	−42°F (−41°C)
Propylene Glycol	−71°F (−57°C)
Dipropylene Glycol ...	−38°F (−39°C)
Tripropylene Glycol ...	−42°F (−41°C)

Table 7.138: Viscosities of Anhydrous Glycols *(23)*

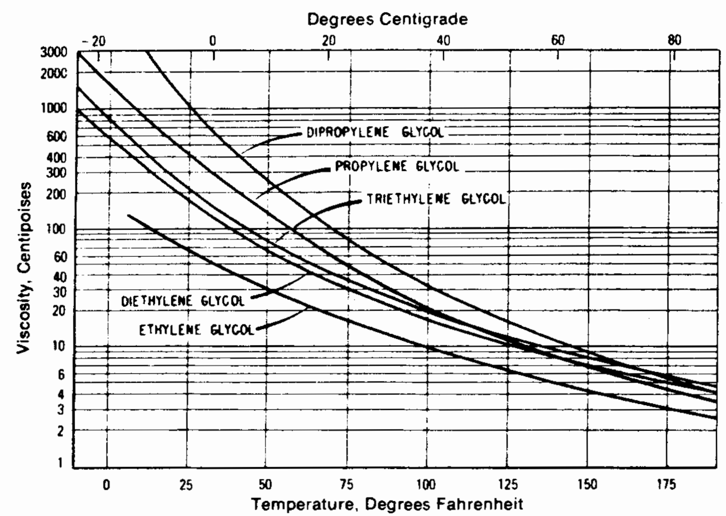


Table 7.139: Viscosities of Aqueous Ethylene Glycol Solutions *(23)*

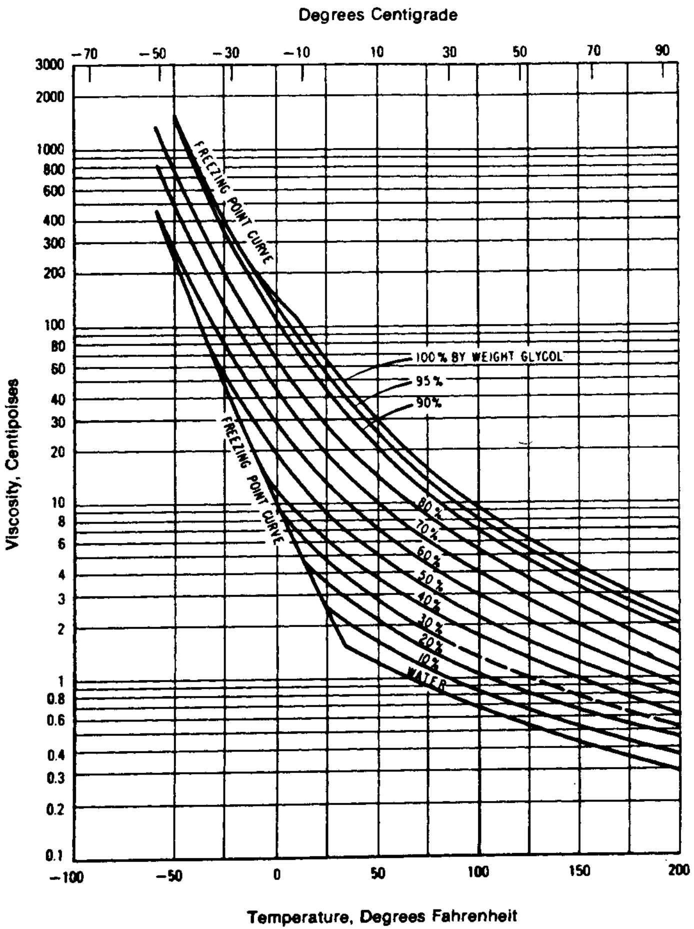


Table 7.140: Viscosities of Aqueous Diethylene Glycol Solutions *(23)*

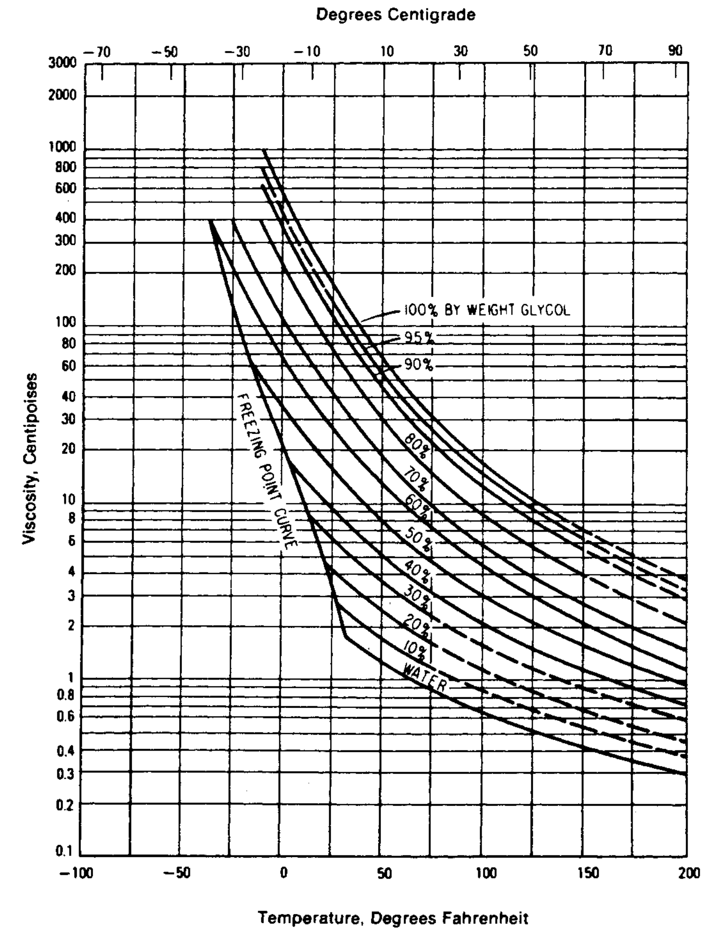


Table 7.141: Viscosities of Aqueous Triethylene Glycol Solutions *(23)*

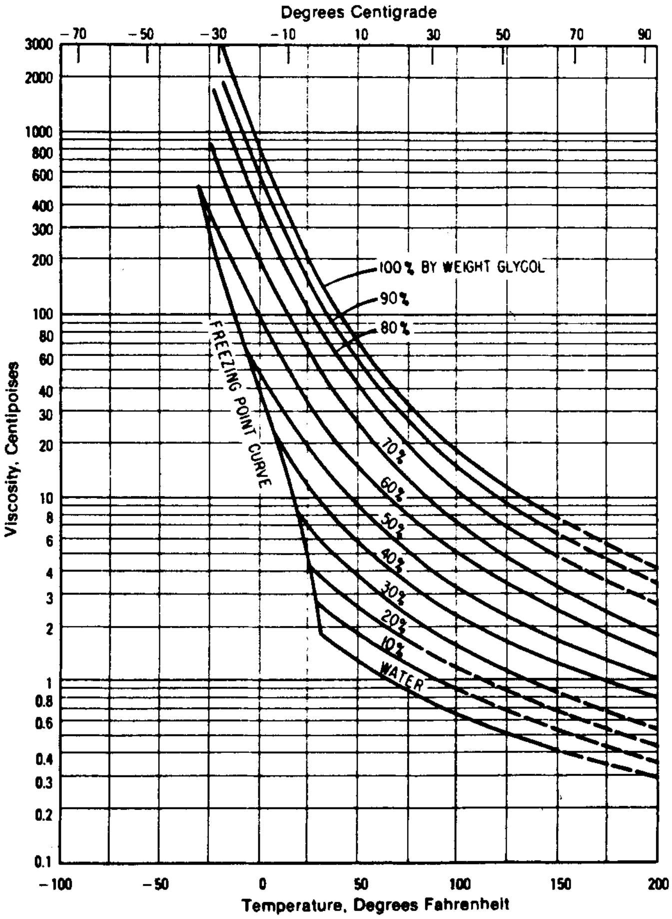


Table 7.142: Viscosities of Aqueous Tetraethylene Glycol Solutions *(23)*

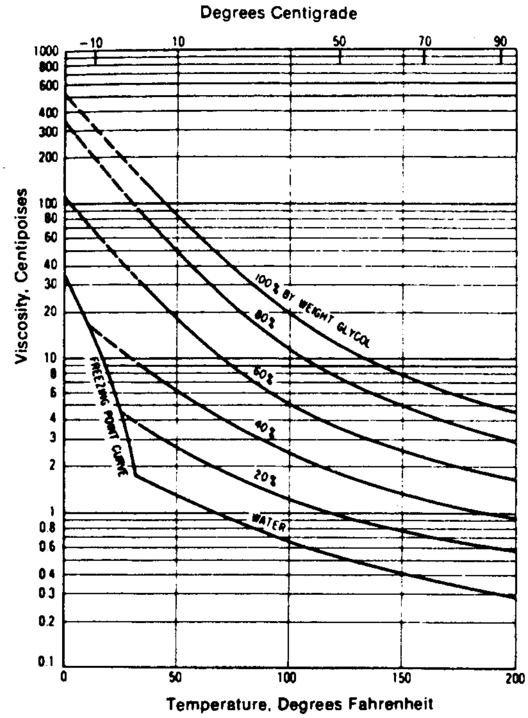


Table 7.143: Viscosities of Aqueous Propylene Glycol Solutions *(23)*

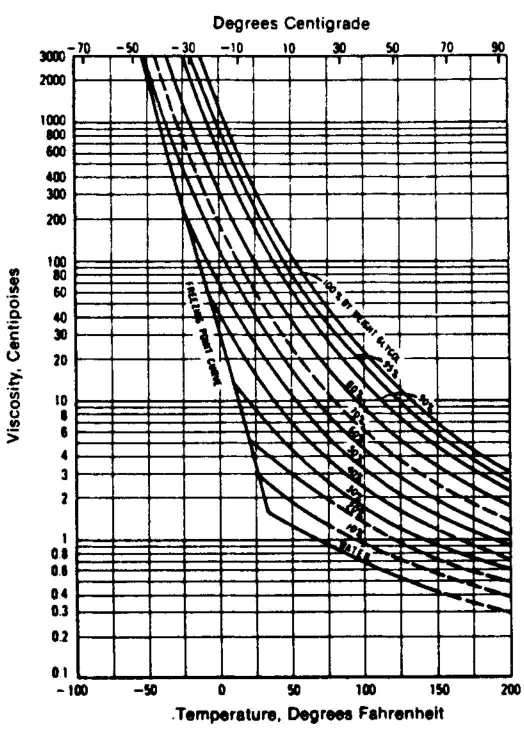


Table 7.144: Viscosities of Aqueous Dipropylene Glycol Solutions *(23)*

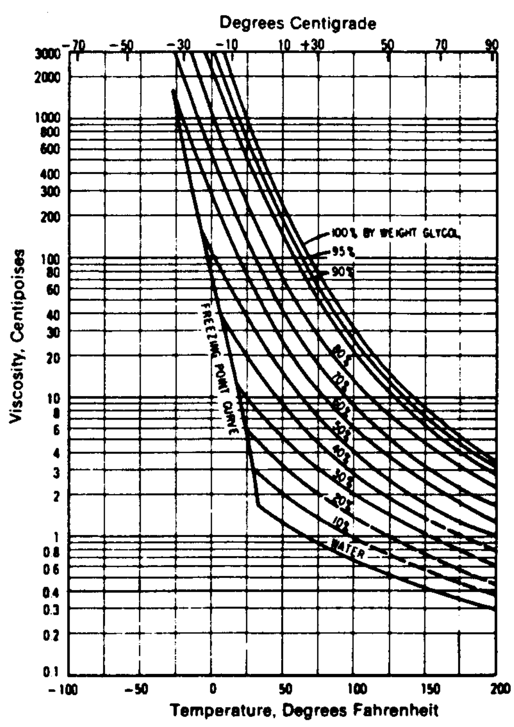


Table 7.145: Viscosities of Aqueous Tripropylene Glycol Solutions *(23)*

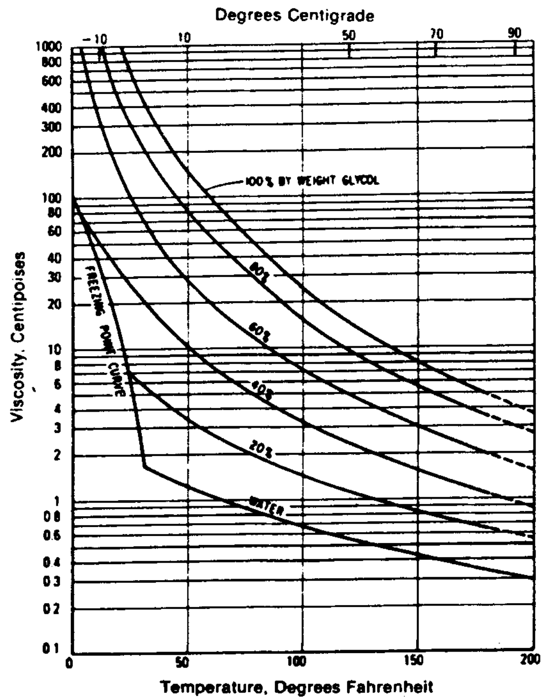


Table 7.146: Freezing Points of Aqueous Glycol Solutions *(23)*

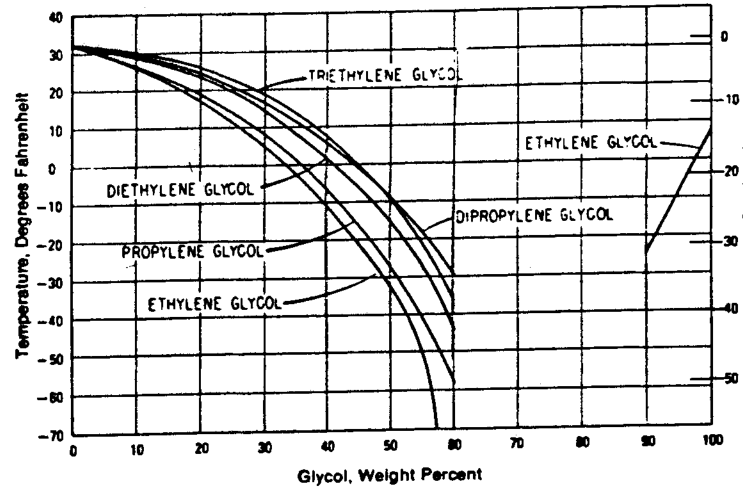


Table 7.147: Specific Heat of Anhydrous Glycols *(23)*

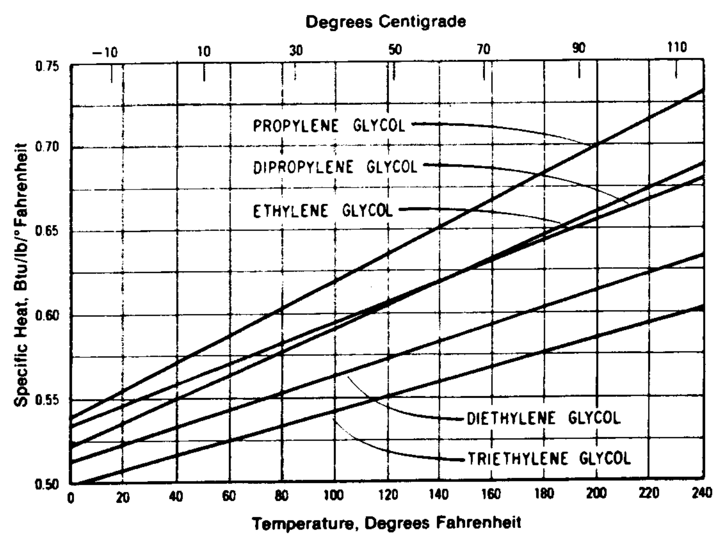


Table 7.148: Specific Heats of Aqueous Glycol Solutions (Btu/lb/°F) *(23)*

Temp. °F	Glycol, % by Weight 100	80	60	40	20	10	Temp. °C
			ETHYLENE GLYCOL				
60	.563	.660	.757	.855	.940	.976	15.6
80	.576	.673	.769	.864	.942	.977	26.7
100	.590	.685	.780	.872	.944	.978	37.8
120	.604	.697	.792	.880	.946	.979	48.9
140	.618	.710	.803	.888	.948	.980	60.0
160	.632	.722	.814	.896	.950	.981	71.1
180	.646	.735	.825	.905	.952	.982	82.2
200	.660	.748	.837	.914	.954	.982	93.3
220	.674	.761	.849	.922	.956	.983	104.4
240	.688	.774	.861	.930	.958	.984	115.5
			DIETHYLENE GLYCOL				
60	.543	.631	.736	.849	.922	.949	15.6
80	.555	.645	.749	.855	.927	.954	26.7
100	.565	.659	.762	.861	.932	.960	37.8
120	.575	.672	.774	.868	.937	.965	48.9
140	.583	.686	.787	.874	.943	.970	60.0
160	.593	.700	.800	.880	.948	.975	71.1
180	.603	.714	.813	.886	.954	.980	82.2
200	.613	.728	.826	.893	.960	.985	93.3
220	.623	.742	.839	.900	.965	.990	104.4
240	.634	.756	.852	.907	.971	.995	115.5
			TRIETHYLENE GLYCOL				
60	.525	.637	.749	.866	.935	.979	15.6
80	.534	.648	.758	.872	.938	.980	26.7
100	.540	.659	.768	.878	.941	.981	37.8
120	.550	.669	.777	.884	.944	.981	48.9
140	.562	.680	.787	.890	.946	.982	60.0
160	.569	.690	.796	.895	.949	.983	71.1
180	.577	.701	.806	.901	.952	.984	82.2
200	.586	.711	.815	.907	.955	.985	93.3
220	.595	.722	.825	.913	.957	.985	104.4
240	.605	.782	.834	.919	.960	.986	115.5
			PROPYLENE GLYCOL				
60	.587	.687	.795	.900	.970	.985	15.6
80	.603	.702	.808	.907	.972	.986	26.7
100	.619	.717	.821	.913	.975	.988	37.8
120	.635	.733	.833	.919	.977	.990	48.9
140	.651	.748	.846	.925	.980	.991	60.0
160	.667	.763	.857	.930	.983	.992	71.1
180	.683	.778	.871	.936	.984	.994	82.2
200	.699	.794	.882	.944	.987	.995	93.3
220	.715	.809	.895	.949	.990	.996	104.4
240	.731	.824	.907	.954	.993	.998	115.5
			DIPROPYLENE GLYCOL				
60	.570	.687	.801	.900	.967	.985	15.6
80	.582	.698	.810	.905	.970	.986	26.7
100	.594	.708	.819	.910	.972	.988	37.8
120	.606	.718	.828	.915	.974	.990	48.9
140	.618	.728	.836	.920	.976	.991	60.0
160	.631	.739	.845	.924	.978	.993	71.1
180	.644	.749	.854	.929	.980	.995	82.2
200	.656	.760	.863	.934	.983	.997	93.3
220	.668	.770	.872	.939	.985	.998	104.4
240	.680	.781	.881	.944	.988	.999	115.5

Table 7.149: Densities of Aqueous Ethylene Glycol Solutions (% by wt) *(23)*

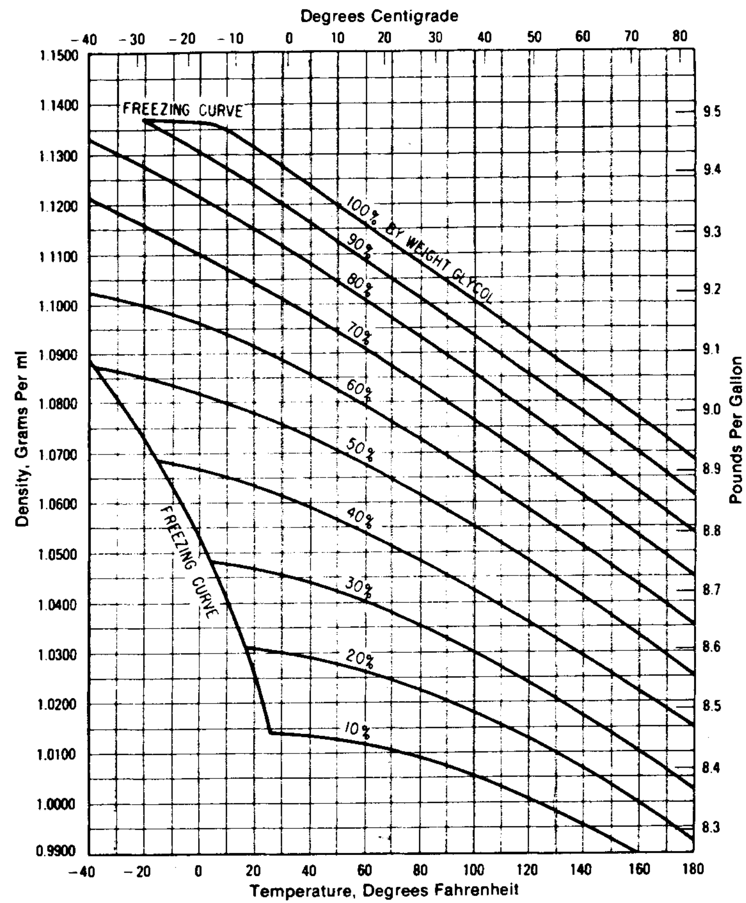


Table 7.150: Densities of Aqueous Diethylene Glycol Solutions (% by wt) *(23)*

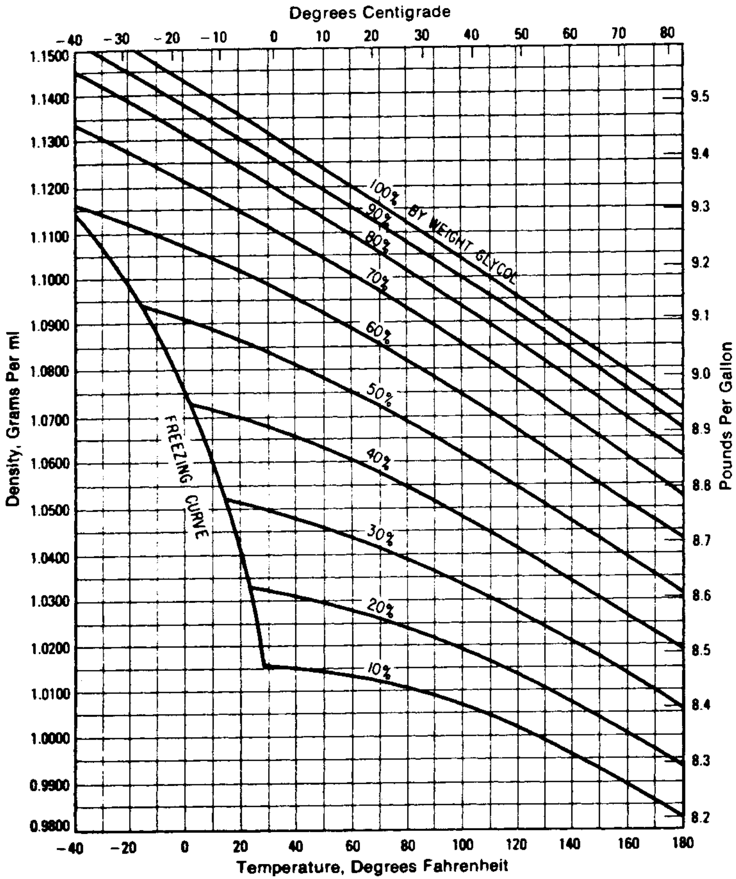


Table 7.151: Densities of Aqueous Triethylene Glycol Solutions (% by wt) *(23)*

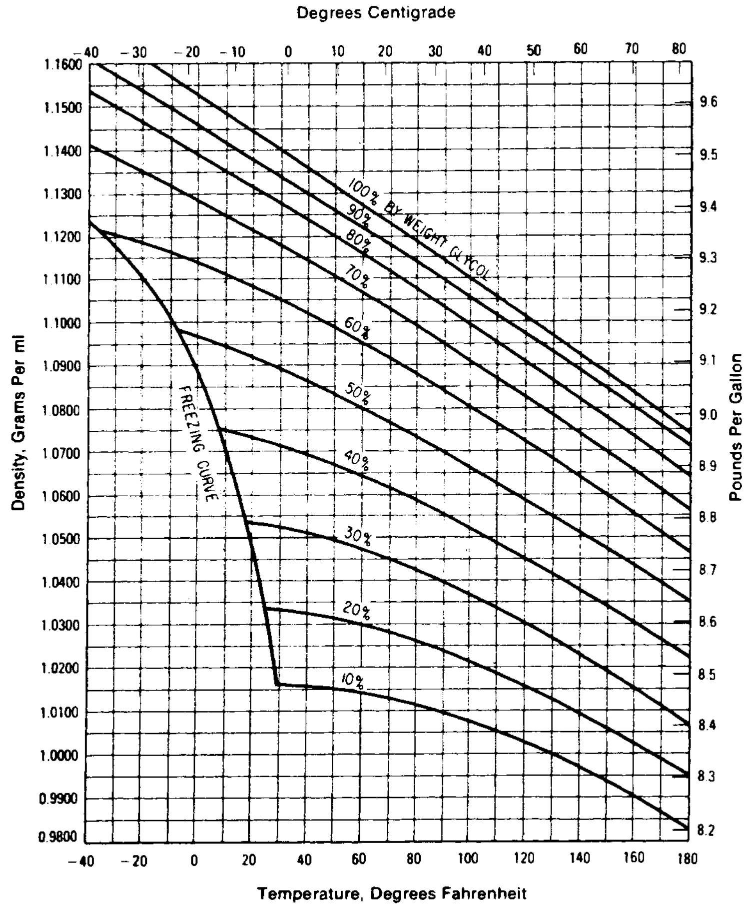


Table 7.152: Densities of Aqueous Tetraethylene Glycol Solutions (% by wt) *(23)*

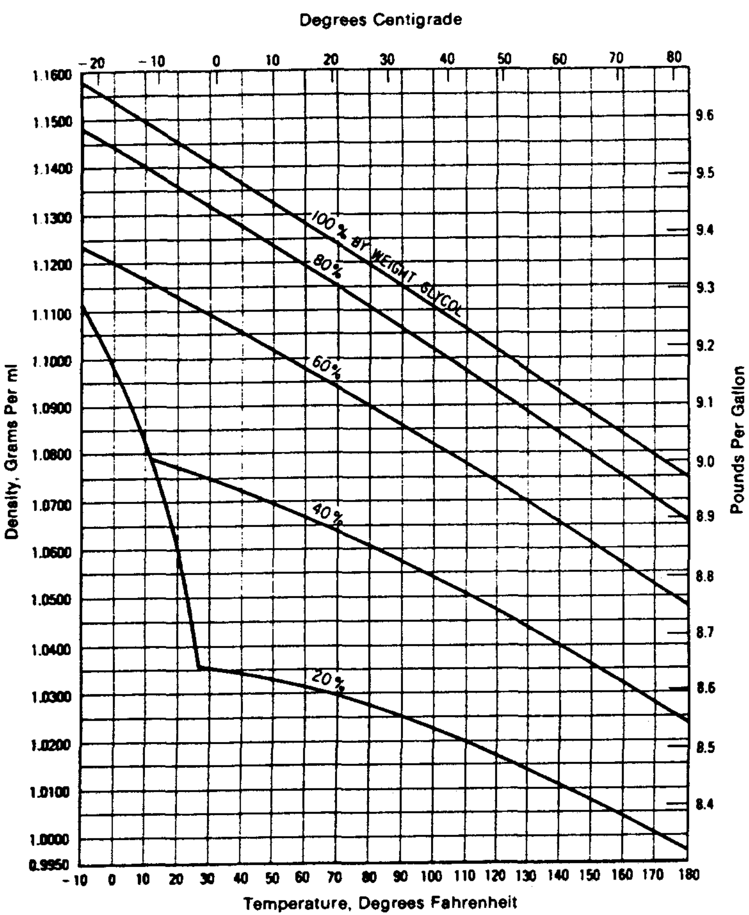


Table 7.153: Densities of Aqueous Propylene Glycol Solutions (% by wt) *(23)*

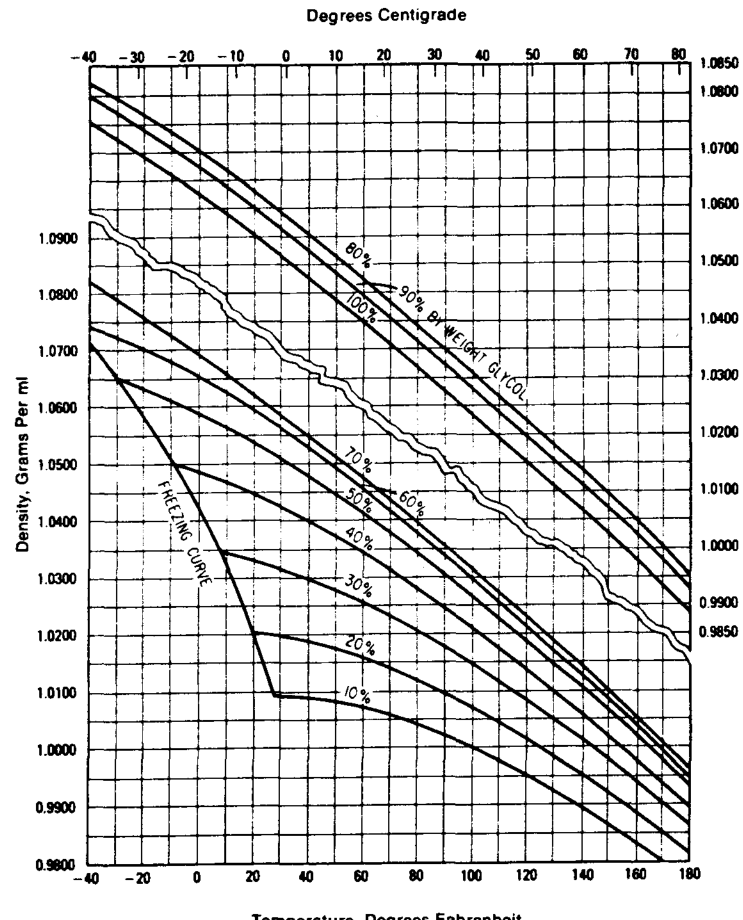


Table 7.154: Densities of Aqueous Dipropylene Glycol Solutions (% by wt) *(23)*

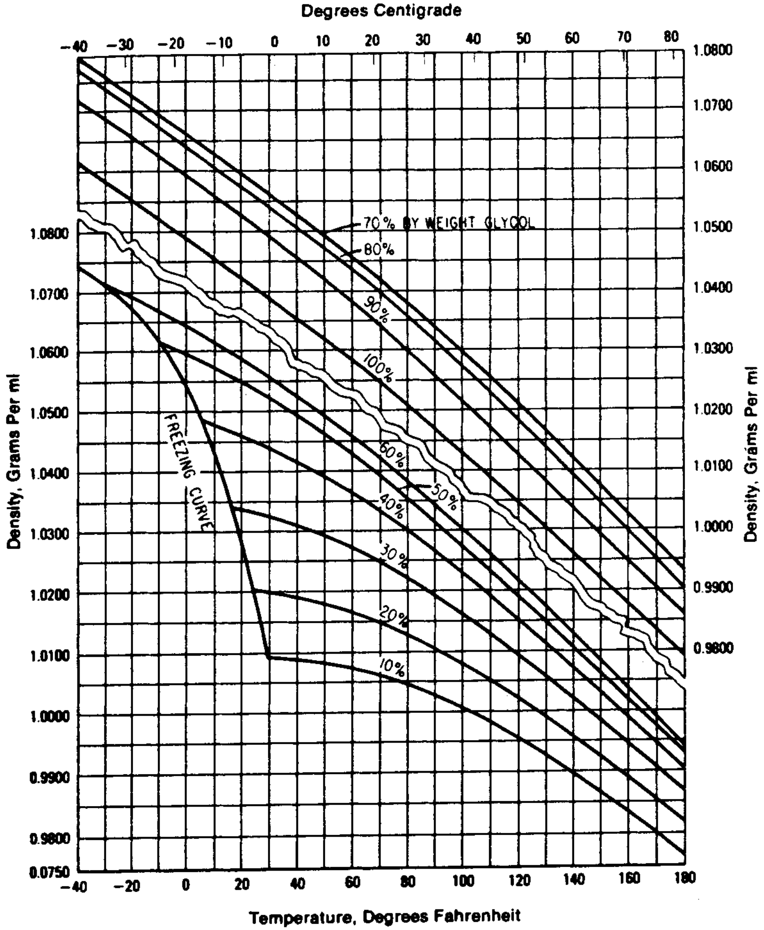


Table 7.155: Densities of Aqueous Tripropylene Glycol Solutions (% by wt) *(23)*

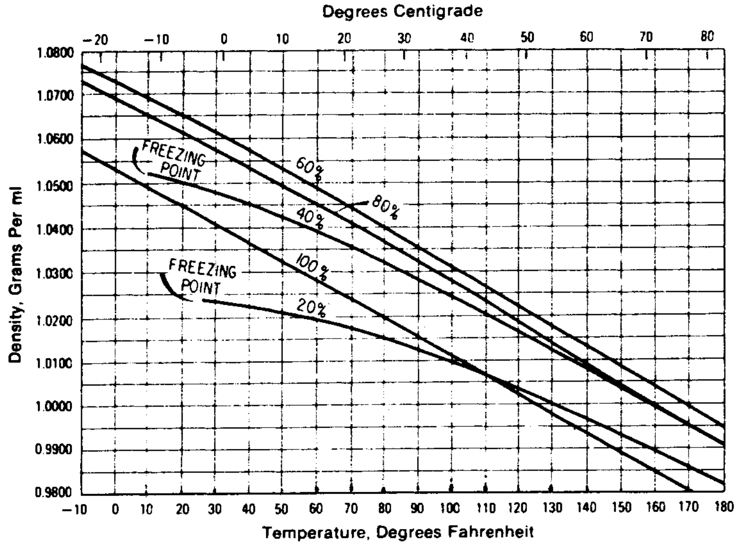


Table 7.156: Surface Tensions of Aqueous Solutions of Glycols at 77°F *(23)*

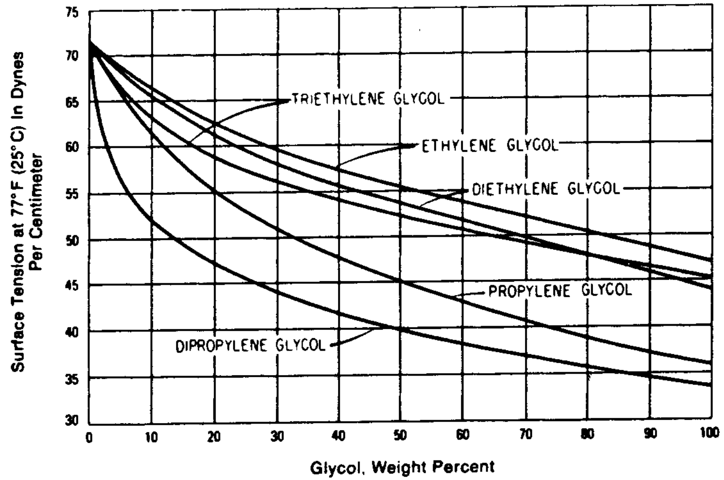


Table 7.157: Flammability of Glycols *(23)*

Glycol	Flash Point °F	Flash Point °C	Fire Point °F	Fire Point °C
Ethylene Glycol	240	116	245	119
Diethylene Glycol	255	124	290	142
Triethylene Glycol	350	177	330	166
Tetraethylene Glycol	400	204	375	191
Propylene Glycol	220	104	220	104
Dipropylene Glycol	260	127	260	127
Tripropylene Glycol	285	141	310	154

Note: Flash points are determined by the ASTM Pensky-Martens Closed Cup Method and fire points by the ASTM Cleveland Open Cup Method.

Table 7.158: Refractive Indices of Aqueous Glycol Solutions at 77°F (25°C) *(23)*

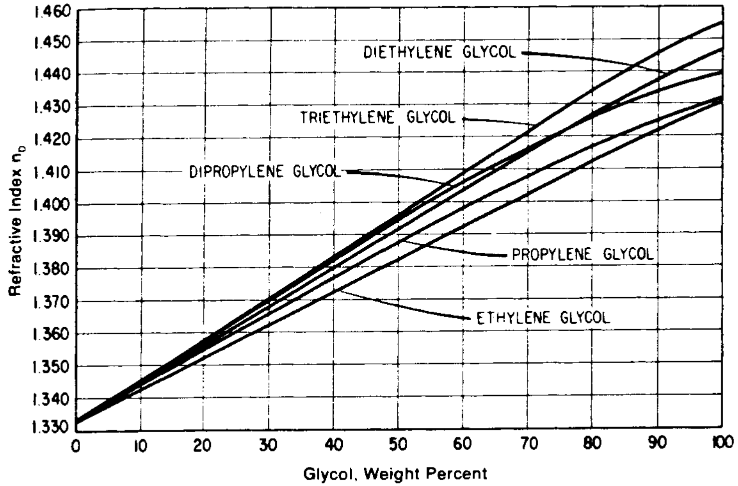


Table 7.159: Conversion Chart for Aqueous Ethylene Glycol Solutions *(23)*

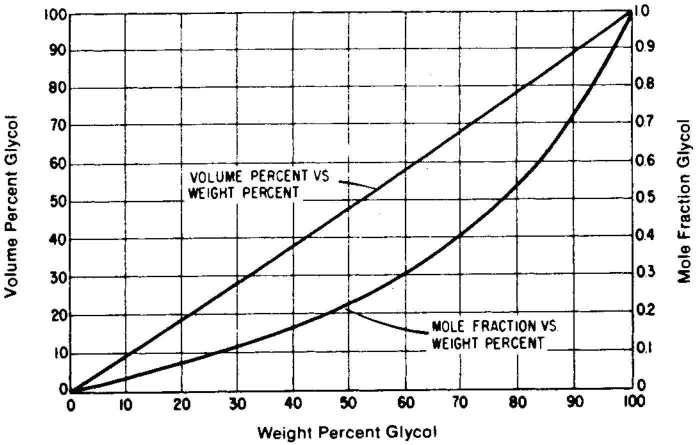


Table 7.160: Conversion Chart for Aqueous Diethylene Glycol Solutions *(23)*

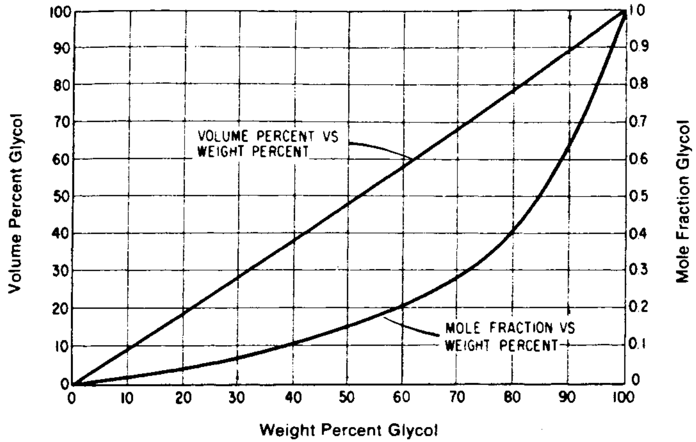


Table 7.161: Conversion Chart for Aqueous Triethylene Glycol Solutions *(23)*

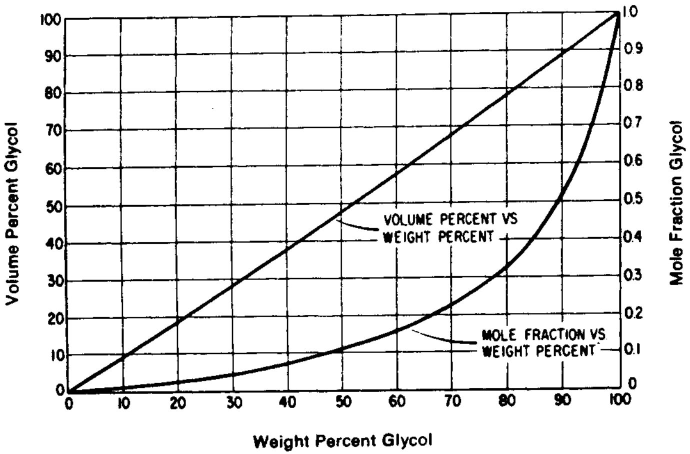


Table 7.162: Conversion Chart for Aqueous Tetraethylene Glycol Solutions *(23)*

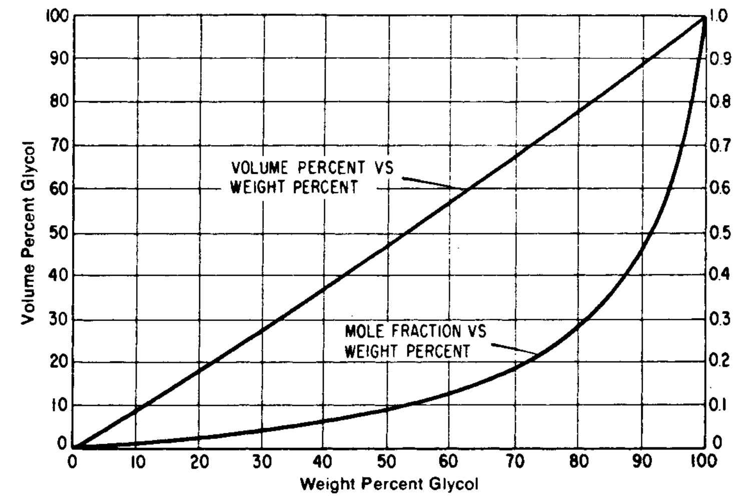


Table 7.163: Conversion Chart for Aqueous Propylene Glycol Solutions *(23)*

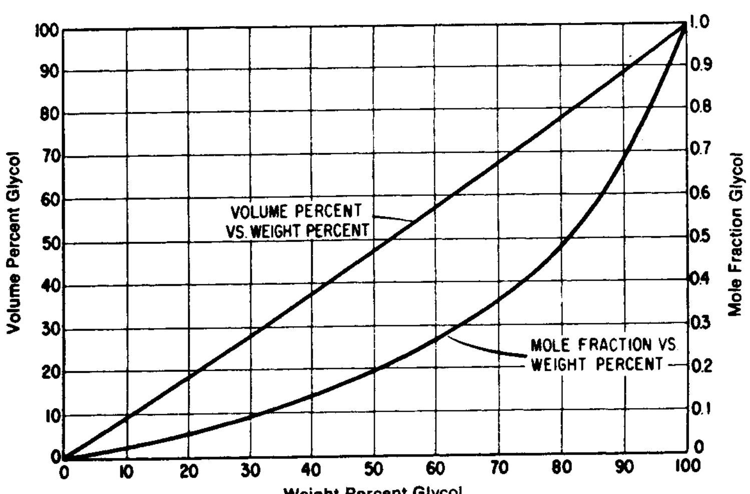


Table 7.164: Conversion Chart for Aqueous Dipropylene Glycol Solutions *(23)*

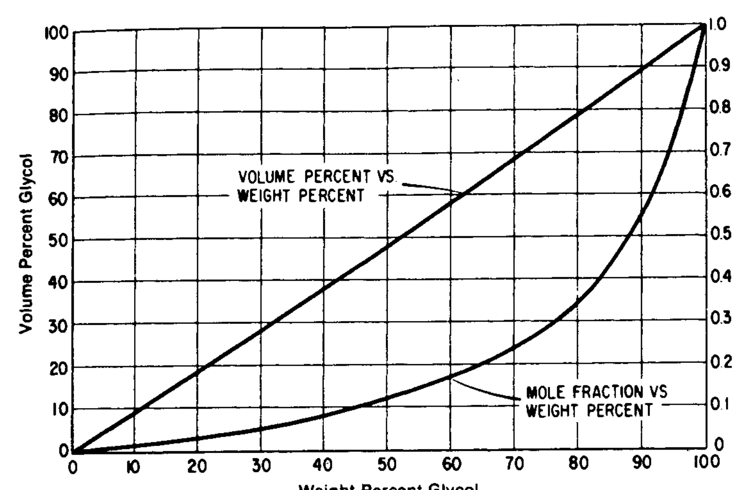


Table 7.165: Conversion Chart for Aqueous Tripropylene Glycol Solutions *(23)*

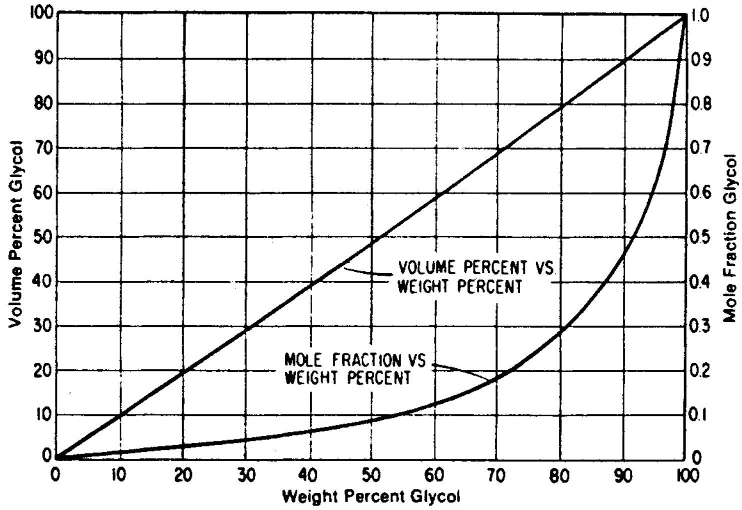
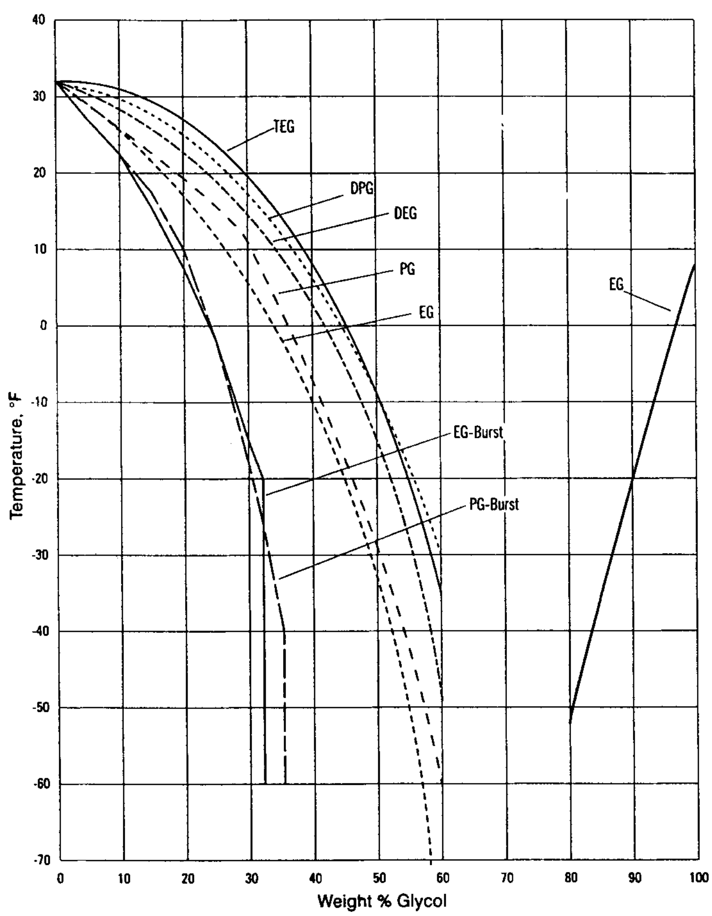


Table 7.166: Freeze Points and Burst Points of Aqueous Solutions *(23)*



Note: It should be remembered that the freezing points are the temperatures at which the first crystals form, and that even below these temperatures, a slushy solution exists which will still flow.

Table 7.167: Solubility of Various Compounds in Glycols *(23)*

S = Completely Soluble I = Insoluble < = Less Than > = Greater Than	Ethylene Glycol	Diethylene Glycol	Triethylene Glycol	Tetraethylene Glycol	Propylene Glycol	Di-propylene Glycol	Tri-propylene Glycol
Benzene	5.7	31.3	S	S	19.2	S	S
Carbon Tetrachloride[1]	6.2	26.2	33.6	62	23.4	S	S
Dibutyl Phthalate	0.5	10.6	16.5	S	8.1	S	S
Dichloroethyl Ether	10.6	S	S	S	37.1	S	S
Diethanolamine[1]	S	S	S	S	S	S	S
DOWANOL* PM Glycol Ether[1]	S	S	S	S	S	S	S
DOWANOL* DPM Glycol Ether[1]	S	S	S	S	S	S	S
Ethyl Alcohol	S	S	S	S	S	S	S
Ethyl Ether	8.2	16.3	16.9	20	S	S	S
Methyl Alcohol	S	S	S	S	S	S	S
Methyl Isobutyl Carbinol	S	S	S	S	S	S	S
Methyl Isobutyl Ketone	12	S	S	S	S	S	S
Monochlorobenzene	5.7	S	S	S	22.5	S	S
Monoethanolamine[1]	S	S	S	S	S	S	S
ortho-Dichlorobenzene	4.5	48.4	S	S	19.4	S	S
Perchloroethylene[1]	0.7	10.7	15.0	19.0	14.5	S	S
Phenol[1]	S	S	S	S	S	S	S
Styrene[1]	3.4	36	S	S	15	S	S
Toluene	2.9	17.2	24.8	89	12.3	S	S
Urea	48	30	37	28	29	12	10
Castor Oil	1	<0.5	<0.5	<1	0.8	S	S
Coconut Oil	1	1	1	<1	1	1	3
Cottonseed Oil	1	1	1	<1	1	1	<1
Hydrous Wool Fat	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Lard Oil	1	1	1	<1	1	1	<1
Linseed Oil	1	1	1	<1	1	1.4	2.5
Oiticica Oil	<1	<1	<1	<1	<1	<1	<1
Olive Oil	1	1	1	<1	1	0.7	1.5
Pine Oil	S	S	S	S	S	S	S
Soya Bean Oil	1	1	1	<1	1	1	<1
Sperm Oil	1	1	1	<1	1	1	<1
Tall Oil	<1	<1	<1	<1	<1	S	S
Tung Oil	1	1	1	<1	1	1	<1
Turkey Red Oil	<1	<1[2]	1[2]	1[2]	<1[2]	3[2]	4[2]
Paraffin Oil	1	1	1	<1	1	1	<1
SAE No. 10 Oil	1	1	1	<1	1	1	<1
VMP Naphtha	<1	<1	<1	1	1	10	14
Animal Glue (Dry)	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Dextrin	<1	<1	<1	<1	<1	<1	<1
Gum Damar	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Kauri Gum	<0.5	<0.5	<0.5	>16[3]	<5	<5	>16[3]
Sudan III	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1
Shellac	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<1

[1] Product of The Dow Chemical Company
[2] Forms stable emulsion from this concentration to 100%
[3] Becomes too viscous to stir beyond 16%.

Table 7.168: Viscosity of Anhydrous Glycols *(23)*

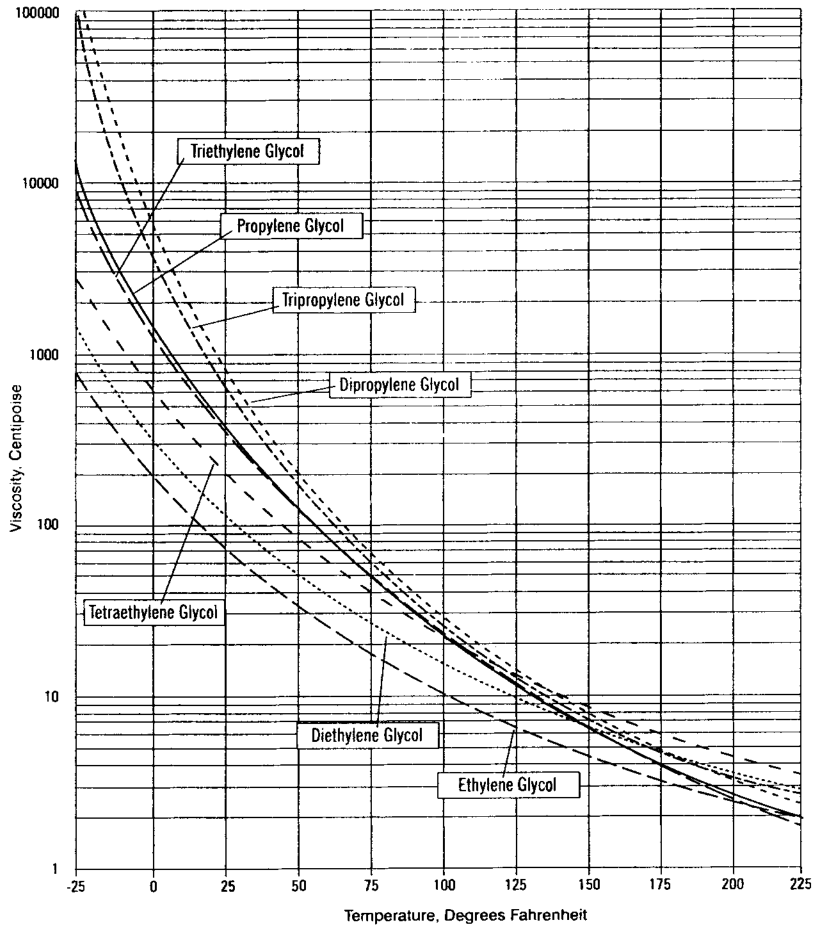


Table 7.169: Specific Heat of Anhydrous Glycols *(23)*

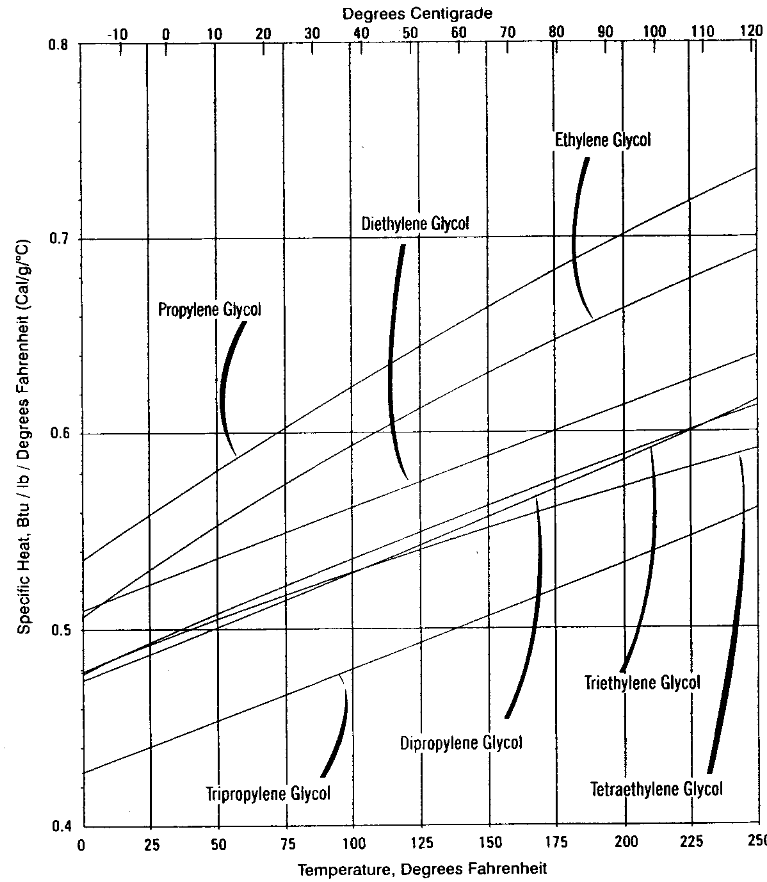


Table 7.170: Technical Data: Ethylene Glycol Products *(27)*

Parameters		MEG	DEG	TEG
Chemical formula		$C_2H_6O_2$	$C_4H_{10}O_3$	$C_6H_{14}O_4$
CAS #		107-21-1	111-46-6	112-27-6
HMIS rating:	Health hazard	1*	1	1
	Fire hazard	1	1	1
	Reactivity	0	0	0
Molecular weight		62.07	106.1	150.17
Specific gravity at 20/20°C		1.1154	1.118	1.125
Weight/gal (US) in lbs at 20°C		9.28	9.31	9.36
Refractive index at 20°C		1.4316	1.447	1.4559
Viscosity at 20°C, cP		21	54	64
Flash point (PMCC), °F (°C)		244 (118)	280 (138)	340 (171)
Boiling point, °C (°F)		197.6 (387.1)	245 (473)	287.4 (549.5)
Freezing point, °C (°F)		-13 (8.6)	-8 (17.6)	-7.2 (19)
Vapor density		2.1	2.14	5.2
Explosive limits:	Lower (%)	3.2	1.6	0.9
	Upper (%)	15.3	10.8	9.2
Autoignition temperature, °F (°C)		752 (399)	442 (227)	699 (370)
Vapor pressure at 20°C, mm Hg		0.06	< 0.01	< 0.01
Surface tension at 20°C, dyne/cm		48.4	44.7	45.2
Specific heat at 20°C, cal/g/°C		0.56	0.50	0.53
Coefficient of expansion, per °C (10° - 40°C)		0.00062	0.00064	0.00068

Table 7.171: Ethylene Glycol Compatibility *(27)*

Acceptable Metals	Acceptable Non-Metals
Aluminum (to 100°F)	Butyl GR-1 (IIR)
Brass (to 80°F)	Carbon graphite resin impregnated
Bronze	Chlorinated Polyether
Carbon steel (to 100°F)	CPVC
Hastelloy B®	Ethylene Propylene Diene (EPDM)
Hastelloy C®	Epoxy Compounds
High silicon iron	Ethylene-Terefluoroethylene (ETFE, Tefzel®)
Inconel®	Fluorinated Ethylene Propylene (FEP)
Lead (to 90°F)	Fluoroelastomers (FKM, Viton A®, Fluorel®)
Monel®	Furfural Alcohol (Furans)
Nickel	Modified Phenylene oxide (Noryl®)
Nickel resist	Natural Rubber
304/347 Stainless steel	Perfluoroalkoxy (PFA)
316 Stainless steel	Perfluoroelastomers (FPM, Kalrez®, Chemraz®, Kel-F®)
20Cb3 Stainless steel	Phenolics
Tantalum (to 90°F)	Polyamides (Nylon® 12, Nylon® 66)
Titanium	Polybutadiene (Isoprene)
Zirconium	Polychloroprene (Neoprene®)
	Polyester Terephthalate (PET)
	Polyethylene
	Polypropylene
	Polystyrenes
	Polysulfones
	Polyphenylene Sulfides (Ryton®)
	Polyvinylidene fluoride (PVDF, Kynar®)
	Silicone Rubbers
	Vinyl Ester

Registered Trademarks	
Teflon®, Kalrez®, Nylon®	Registered trademark of E. I. du Pont de Neumois
Neoprene®, Tefzel®, Viton A®	Registered trademark of E. I. du Pont de Neumois
Chemraz®	Registered trademark of Green, Tweed & Co., Inc.
Buna-N®	Registered trademark of Mobay Corporation
Hastelloy B®, Hastelloy C®	Registered trademark of Cabot Corporation
Inconel®, Monel®	Registered trademark of Inco Alloys International
Fluorel®, Kel-F®	Registered trademark of 3-M Corporation
Noryl®	Registered trademark of General Electric Co.
Ryton®	Registered trademark of Phillips Petroleum Corp.
Kynar®	Registered trademark of Pennwalt Corporation

Table 7.172: Weight per Gallon at Various Temperatures (lb) *(27)*

Temperature, °F	MEG	DEG	TEG
40	9.383	9.410	9.480
45	9.366	9.394	9.461
50	9.349	9.379	9.444
55	9.334	9.361	9.424
60	9.318	9.344	9.405
65	9.301	9.328	9.389
70	9.286	9.312	9.370
75	9.268	9.294	9.352
80	9.253	9.278	9.334
85	9.235	9.261	9.315
90	9.218	9.245	9.297
95	9.202	9.228	9.278
100	9.185	9.211	9.261

Table 7.173: Weight Percent vs Volume Percent Aq. Monoethylene Glycol Solutions, 20°C *(27)*

Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %
0	0	34	31.6	68	65.6
2	1.8	36	33.5	70	67.7
4	3.6	38	35.5	72	69.7
6	5.4	40	37.4	74	71.8
8	7.2	42	39.4	76	74.0
10	9.1	44	41.3	78	76.1
12	10.9	46	43.3	80	78.2
14	12.7	48	45.3	82	80.3
16	14.6	50	47.3	84	82.5
18	16.4	52	49.3	86	84.6
20	18.3	54	51.3	88	86.8
22	20.2	56	53.3	90	89.0
24	22.1	58	55.3	92	91.2
26	24.0	60	57.4	94	93.4
28	25.9	62	59.4	96	95.6
30	27.8	64	61.4	98	97.8
32	29.7	66	63.5	100	100

Table 7.174: Specific Gravity vs Composition @ Various Temperatures of Aqueous MEG Solutions *(27)*

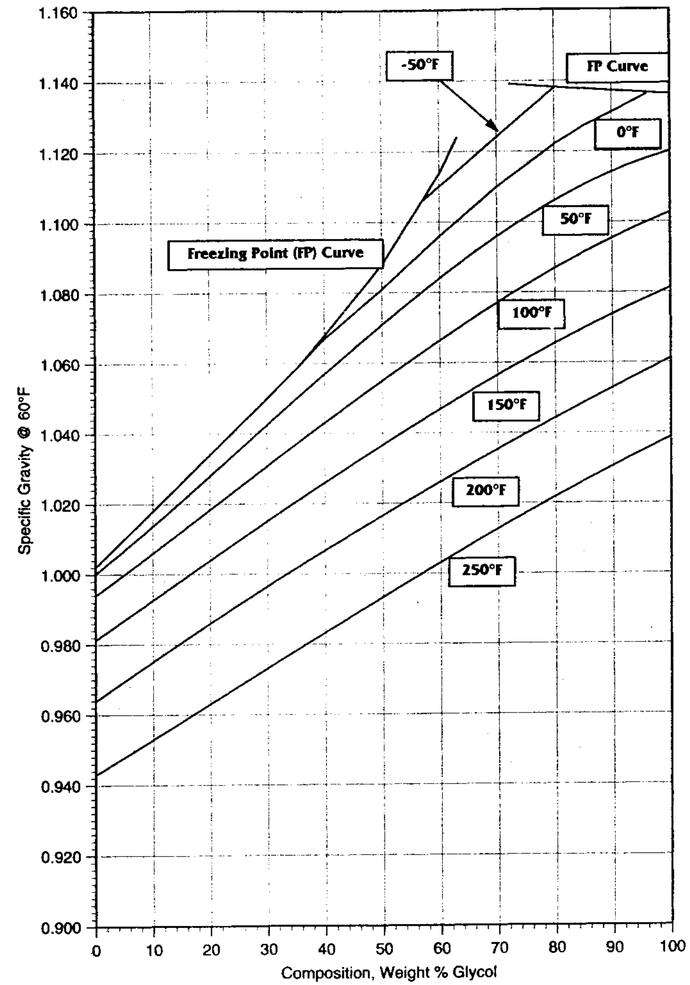


Table 7.175: Specific Gravity vs Composition @ Various Temperatures of Aqueous DEG Solutions *(27)*

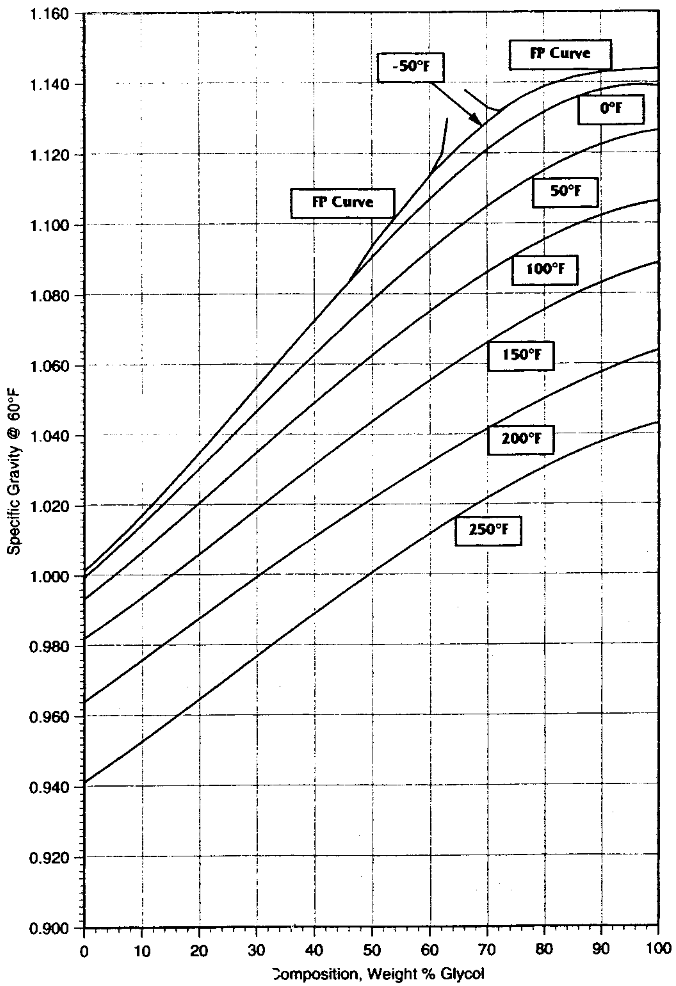


Table 7.176: Specific Gravity vs Composition @ Various Temperatures of Aqueous TEG Solutions *(27)*

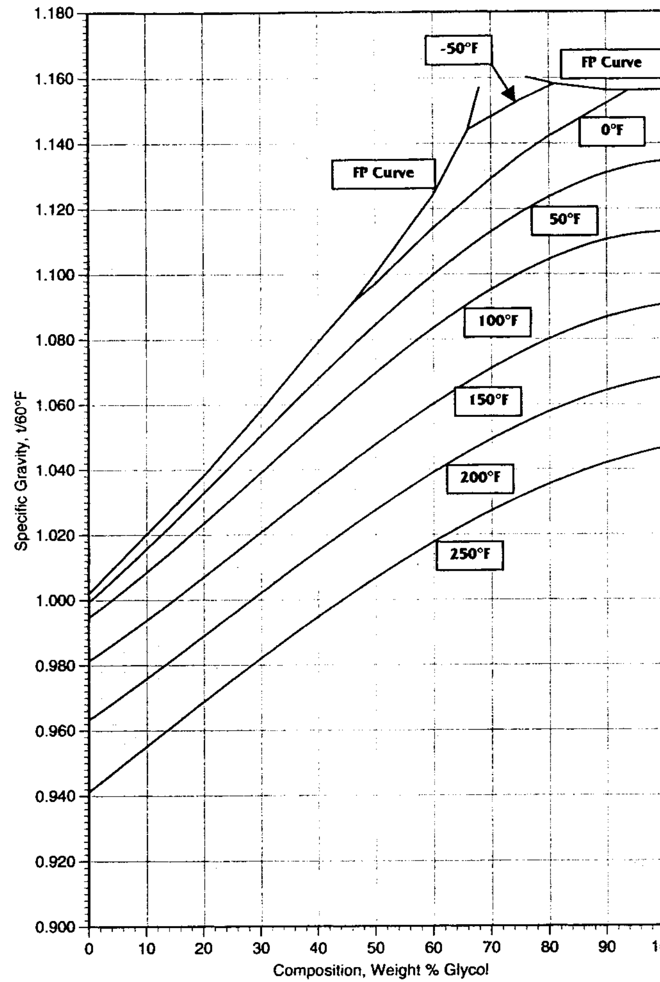


Table 7.177: Boiling Point @ 760 mm Hg vs Composition of Aqueous Glycol Solutions *(27)*

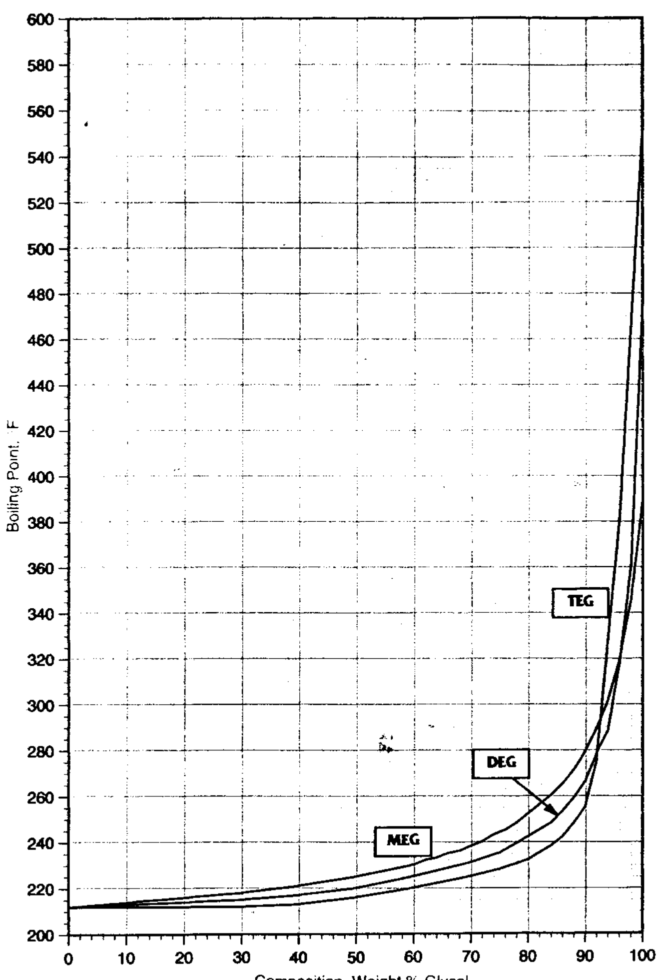


Table 7.178: Freezing Point vs Composition of Aqueous Glycol Solutions *(27)*

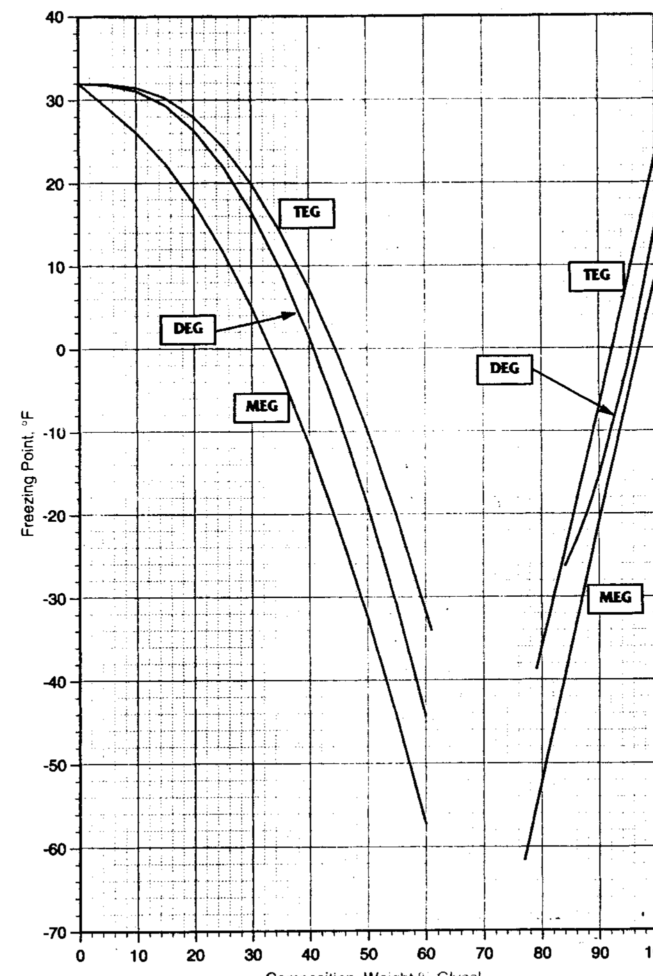


Table 7.179: Vapor Pressure vs Temperature of the Glycols *(27)*

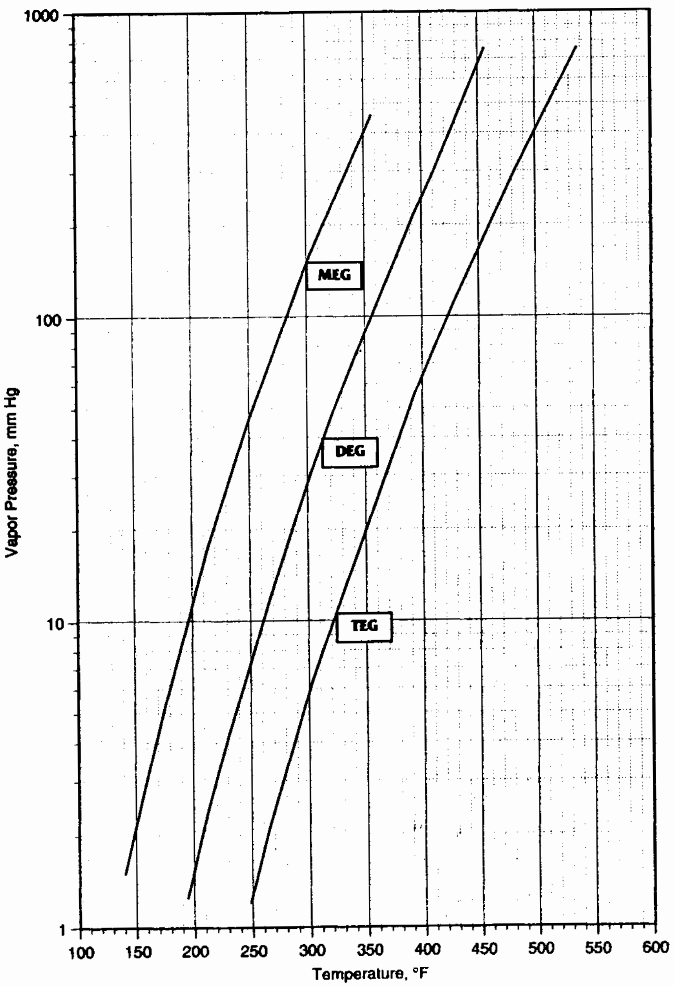


Table 7.180: Viscosity vs Temperature of the Glycols *(27)*

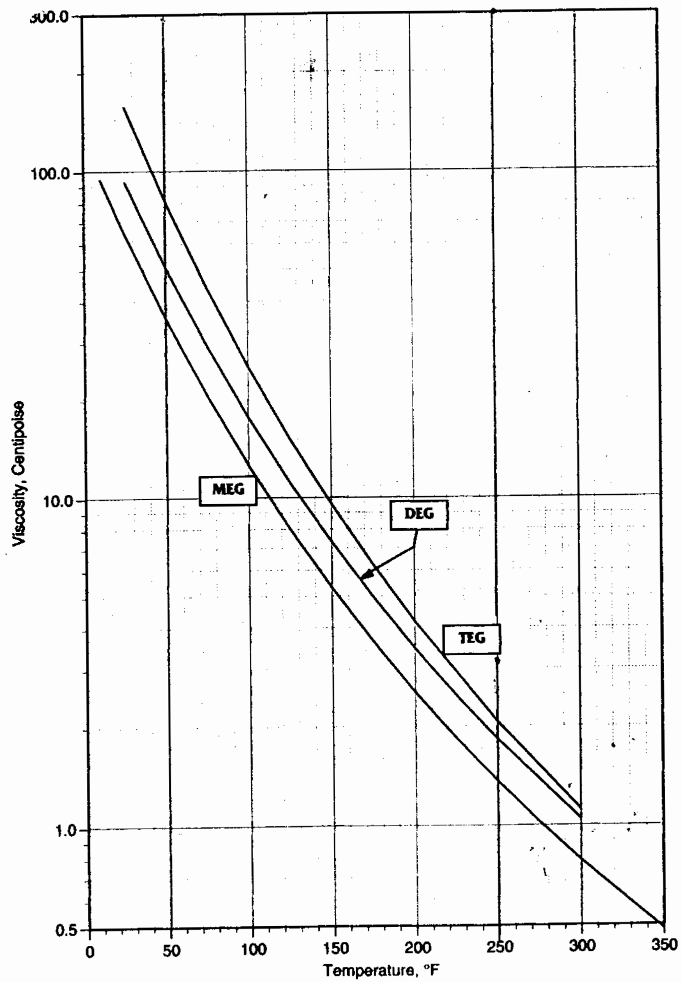


Table 7.181: Fire Hazard Information *(23)*

Glycol	Flammable Limits Vol % Lower	Flammable Limits Vol % Upper	Auto-Ignition Temp°F[1]	NFPA[2] Hazard Identification Health	Flam.	Reactivity	Flash Point F°	C°
Ethylene Glycol	3.2	-	748	1	1	0	247	119
Diethylene Glycol	-	-	435	1	1	0	281	138
Triethylene Glycol	0.9	9.2	700	1	1	0	325	163
Tetraethylene Glycol	-	-	-	1	1	0	400	204
Propylene Glycol	2.6	12.5	700	0	1	0	218	103
Dipropylene Glycol	-	-	-	0	1	0	250	121
Tripropylene Glycol	-	-	-	0	1	0	285	141

[1]In presence of air
[2]NFPA – National Fire Protection Association

Table 7.182: Acute Oral Toxicity *(23)*

LD_{50} Values for Various Glycols
Single Doses to Rats

Glycol	LD_{50} gm/kg
Ethylene	6.1
Diethylene	16.6
Triethylene	22.0
Tetraethylene	32.8
Propylene	33.7
Dipropylene	14.8
Tripropylene	3.0†

†Largest dose survived by all rats tested: 10.0 gm/kg resulted in the death of all the rats tested.

Table 7.183: Environmental Considerations, Biodegradation *(23)*

Glycol	Biodegradation ThOD[2]	BOD[3] - 20 Day
Ethylene Glycol	1.29p/p[4]	1.15p/p
Diethylene Glycol	1.51	0.88
Triethylene Glycol	1.60	0.27
Tetraethylene Glycol	1.65	0.71
Propylene Glycol	1.68	1.45
Dipropylene Glycol	1.91	0.71
Tripropylene Glycol	1.38	—

Table 7.184: Ethylene Glycols: Products, Grades and Specifications *(27)*

Specification	MEG High Purity	MEG Fiber	MEG Industrial	MEG Antifreeze
MEG, wt % min	99.9	99.9	99.0	95.0
DEG, wt % max	0.05	0.05	0.5	5.0
Other glycols, wt % max			0.1	
Color, APHA max	5	5	10	15
Acidity, wt % as Acetic Acid, max	0.003	0.003	0.005	0.005
Ash, wt % max	0.003	0.003	0.005	0.005
Chlorides (as Cl), ppm max	0.1	0.1		
Iron, ppm max	0.07	0.07		
Water, wt % max	0.05	0.05	0.2	0.5
Specific resistivity, ohm-cm, min	3×10^6			
UV transmittance, 1/cm				
350 mu %T min	98	98		
275 mu %T min	93	93		
220 mu %T min	70	70		
Distillation range, °C(°F)				
Initial boiling point			193(379)	190(374)
Dry point			201(394)	250(482)

Specifications	DEG Polyester	DEG Industrial	TEG Industrial	TEG Gas Treat.
MEG, wt %	0.2 max	0.5 max		5.0 max
DEG, wt %	99.3 min	99.0 min		1.0 max
TEG, wt %	0.3 max	0.5 max	99.0 min	95.0 min
Other glycols			1.0	
Color, APHA max	10	15	25	25
Color, sulfuric test APHA	30			
Acidity, wt % as Acetic Acid, max	0.003	0.005	0.005	0.01
Ash, wt % max	0.003	0.005	0.005	0.005
Water, wt % max	0.1	0.2	0.1	0.1
Distillation range, °C(°F)				
Initial boiling point		242(468)	278(532)	
Dry point		250(482)	300(572)	

Specifications are subject to change. This section is intended for comparison use only. Please contact your sales representative or Technical Service for the current sales specification.

Table 7.185: Ashland Glycols *(69)*

PRODUCT	LB./GAL. 20° C	SP. GR. 20°/20° C	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F COC
Propylene Glycol	8.64	1.038	186-190	367-374	225
Ethylene Glycol	9.28	1.115	193-204	379-399	240
Hexylene Glycol	7.68	0.923	196-199	385-390	215
Dipropylene Glycol	8.51	1.023	228-236	442-457	280
Diethylene Glycol	9.31	1.119	240-250	464-482	290
Tripropylene Glycol	8.52	1.023	263-280	505-536	310
Triethylene Glycol	9.36	1.125	278-300	532-572	330

Table 7.186: Chemcentral Polyols *(67)*

POLYOLS	CAS	Mole Weight	% Purity Comm Prod.	Spec. Grav. @ 25/25°C	Lbs./Gal. @ 25°C	Coeff. of Expan. Per °C	Δ Sp. Gr Per °C	Refractive Index @ 25°C	Distillation Range @ 760 mm Hg	
									°C	°F
ETHYLENE GLYCOL	107-21-1	62.1		1.110	9.26	.00064	.00046	1.430	197-204	387-399
DIETHYLENE GLYCOL	111-46-6	106.1		1.113	9.29	.00065	.00046	1.446	245-255	473-491
TRIETHYLENE GLYCOL	112-27-6	150.2		1.119	9.34	.00071	.00052	1.454	286-300	546-572
PROPYLENE GLYCOL	57-55-6	76.1		1.033	8.62	.00072	.00050	1.431	187-190	369-374
DIPROPYLENE GLYCOL	**25265-71-8**	**134.2**		**1.023**	**8.54**	**.00075**	**.00052**	**1.439**	**231-238**	**448-460**
TRIPROPYLENE GLYCOL	1638-16-0	192.3		1.016	8.51	.00070	.00046	1.442	268-275	514-527
1-3 BUTYLENE GLYCOL	107-88-00	90.12	95	1.006*	8.38*			1.440	200-215	392-419
HEXYLENE GLYCOL	107-41-5	118.18		.923	7.68	.00078	.00052	1.4263†	196-199	385-390
GLYCERINE SYNTHETIC	56-81-5	92.1	99.5	1.262	10.50	.000612	.000615	1.472	290	554
GLYCERINE SYNTHETIC U.S.P.	**56-81-5**	**92.1**	**96.0**	**1.2517**	**10.41**	**.000612**	**.000615**	**1.468**	**175**	**347**
GLYCERINE SYN. 99.5% U.S.P.	56-81-5	92.1	99.5	1.266	10.50	.000612	.000615	1.472	290	554
POLYGLYCOL E200		200		1.124	9.35			1.459	NON-DISTILLABLE	
POLYGLYCOL E300		300		1.125	9.36			1.463		
POLYGLYCOL E400 & E400 NF		400		1.125	9.36			1.465		
POLYGLYCOL E600		**600**		**1.126**	**9.37**			**1.466**		
POLYGLYCOL E1000		1000		1.117	Solid			Solid		
POLYGLYCOL E1450		1450		1.210	Solid			Solid		
POLYGLYCOL E4500		4500		1.212	Solid	.00072		Solid		
POLYGLYCOL P-425		425		1.007	8.38			1.445		
POLYGLYCOL P-1200		**1200**		**1.003**	**8.35**			**1.448**		
POLYGLYCOL P-2000		2000		1.002	8.34			1.450		
POLYGLYCOL P-4000		4000		1.001	8.33			1.449		
POLYGLYCOL 15-200		2600		1.053	8.76			1.459		
POLYGLYCOL 112-2				1.023	8.51			1.454		

POLYOLS	Vapor Press. @ 25°C mm Hg	Visc. cs @ 25°C	Solubility % by Wt. @ 25°C		Spec. Heat @ 25°C B.T.U./lb./°F	Freeze Point °F	Flash Point O. Cup °F	Explosive Limits % by Vol. In Air		Solubility Parameter
			In H_2O	Of H_2O				Lower	Upper	
ETHYLENE GLYCOL	0.12	14.9	∞	∞	0.58	-8	240	3.2	15.3	17.1
DIETHYLENE GLYCOL	< 0.01	25.3	∞	∞	0.55	8	290	1.7	10.6	14.2
TRIETHYLENE GLYCOL	0.01	33.3	∞	∞	0.53	-7	320	0.9	9.2	10.7
PROPYLENE GLYCOL	0.22	42.6	∞	∞	0.60	Supercools	215	2.6	12.5	15.0
DIPROPYLENE GLYCOL	**0.03**	**72.5**	**∞**	**∞**	**0.58**	**Supercools**	**260**	**1.3**	**8.5**	**11.5**
TRIPROPYLENE GLYCOL	< 0.01	55.1	∞	∞	0.51	Supercools	285			9.2
1-3 BUTYLENE GLYCOL	0.06		∞	∞		< -50	250	1.2	8.1	11.6
HEXYLENE GLYCOL	0.05		∞	∞		-50	215	1.2	8.1	11.6
GLYCERINE SYNTHETIC	< 0.01		∞	∞	0.577	17.9	350			17.7
GLYCERINE SYNTHETIC U.S.P.		**435**	**∞**	**∞**		**9.5**	**375**			**17.7**
GLYCERINE SYN. 99.5% U.S.P.	< 0.01		∞	∞	0.577	17.9	350			17.7
POLYGLYCOL E200	< 0.01	39.9	∞	∞	0.52	Supercools	360			
POLYGLYCOL E300	0.01	68.8	∞	∞	0.51	15	415			
POLYGLYCOL E400 & E400 NF	< 0.01	90.0	∞	∞	0.50	43	460			
POLYGLYCOL E600	**< 0.01**	**131**	**∞**	**∞**	**0.49**	**73**	**480**			
POLYGLYCOL E1000	< 0.01	Solid	∞	∞		100	490			
POLYGLYCOL E1450	0.01	Solid	∞	∞		113	490			
POLYGLYCOL E4500	0.01	Solid	∞	∞	0.37	133	515			
POLYGLYCOL P-425	< 0.01	70	∞	∞	0.476	56	390			
POLYGLYCOL P-1200	**< 0.01**	**160**	**2**	**8**	**0.449**	**-40**	**460**			
POLYGLYCOL P-2000	< 0.01	230	< 0.1	4	0.432	24	445			
POLYGLYCOL P-4000	< 0.01	1114	< 0.1			20	445			
POLYGLYCOL 15-200	< 0.01	360	∞	∞		40	345‡			
POLYGLYCOL 112-2	< 0.01	659	< 0.1			18	520			

*20/20°C †20°C ‡Pensky-Martens

Table 7.187: Hoechst Celanese 1,3-Butylene Glycol *(42)*

Physical Properties	
Autoignition Temperature, °C	393.9
Boiling Point at 760 mm Hg, °C	207.5
Boiling Point at 760 mm Hg, °F	405.5
Critical Pressure, atmospheres	49.4
Critical Temperature, °C	370.0
Evaporation Rate (BuAc = 1)	Nil
Flash Point, Tag Open Cup, °F	250
Tag Closed Cup, °F	228
Freezing Point, °C	-50
Heat of Combustion, kcal/mole at constant volume	594.7
Heat of Vaporization, btu/lb at normal boiling point	279
Hygroscopicity, water absorbed in 144 hours, 25-28°C	
at 81 percent relative humdity,wt%	38.5
at 47 percent relative humidity,wt%	12.5
at 20 percent relative humidity,wt%	4.3
Molecular Weight	90.12
Refractive Index n_D^{20}	1.4412
Solubility at 20°C, wt % in alcohol, ether, water	Complete
Specific Gravity, 20/20°C	1.005
Specific Heat of Liquid, btu/lb/°F at 68°F	0.505
Surface Tension in Air at 25°C, dynes/cm	37.80
Vapor Density (air = 1)	3.20
Vapor Pressure, 20°C, mm Hg	0.06
Viscosity at 25°C, centipoise	103.9
Weight, pounds per gallon at 20°C (68°F)	8.37

Table 7.188: Occidental Ethylene Glycol

- **Monoethylene Glycol (MEG or EG)**
  Synonyms for monoethylene glycol include: ethylene glycol, 1,2-ethanediol, dihydroxyethane, ethylene alcohol, glycol alcohol, ethylene dihydrate, and glycol.

- **Diethylene Glycol (DEG)**
  Synonyms for diethylene glycol include: 2,2'-oxybisethanol, 2,2'-oxydiethanol, bis(2-hydroxyethyl ether, diglycol,and 2,2'-dihydroxydiethyl ether.

- **Triethylene Glycol (TEG)**
  Synonyms for triethylene glycol include: 1,2-bis (hydroxyethoxy) ethane, 3,6-dioxaoctane-1,8-diol, triglycol, and 2,2'-ethylenedioxydiethanol.

GLYCEROL (GLYCERINE)

1,2,3-Propanetriol $CH_2OH \cdot CHOH \cdot CH_2OH$

Table 7.189: Physical Properties and Specifications of Glycerol *(32)*

Acidity	Neutral to litmus
Ash	0.01% by wt., max.
Auto ignition point (on glass)	804° F†
Boiling point at 760 mm. Hg	290° C*
Boiling points at low pressures: at 1 mm.	125.0° C
5 mm.	153.8° C
10 mm.	167.2° C
20 mm.	182.2° C
40 mm.	198.0° C
Chlorine	0.0005% by wt., max.
Color, Pt-Co (Hazen) standards	20 max.
Fatty acids, mez/100 g.	1 max.
Fire point	400° F†
Flash point, tag open cup	350° F†
tag closed cup	320° F†
Freezing point	17.9° C*
Glycerol	99.5% by wt., min. (sp. gr. at 20° C, in air 1.2626)*
Heat of fusion	47.5 cal./g.
Latent heat of vaporization at 55° C	228.7 g.-cal./g.
at 195° C	197.3 g.-cal./g.
Melting point	17.9° C*
Molecular weight	92.094
Refractive index at 25° F	1.4722†
Specific gravity at 25/25° C	1.262†
Specific heat at 25° C	0.577 cal./g. °C†
Surface tension at 20° C	63.3 dynes/cm.
90° C	58.6 dynes/cm.
150° C	51.9 dynes/cm.
Vapor pressure at 20° C	0.0016 mm. Hg
200° C	42 mm. Hg
Viscosity at 25° C	945 cp.†
Weight per gallon at 25° C	10.50 lb.

*D. R. Stull, Ind. Engl. Chem., 39, 517 (1947).
†ACS Monograph, No. 117.

Table 7.190: Boiling Points and Specific Gravities of Aqueous Glycerol Solutions *(23)*

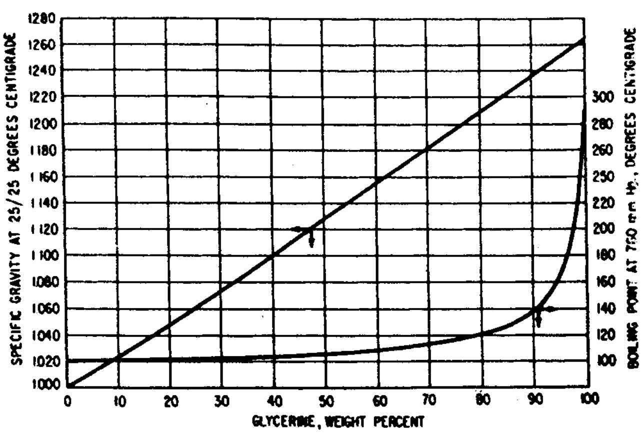


Table 7.191: Conversion Chart for Aqueous Glycerol Solutions (25°C) *(23)*

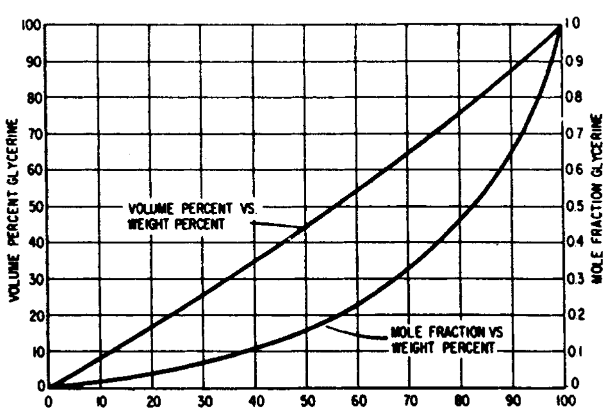


Table 7.192: Density of Glycerol-Water *(23)*

Glycerol (%)	Density at 15°C	15.5°C	20°C	25°C	30°C	Glycerol (%)	Density at 15°C	15.5°C	20°C	25°C	30°C
100	1.26415	1.26381	1.26108	1.25802	1.25495	50	1.12870	1.12845	1.12630	1.12375	1.12110
99	1.26160	1.26125	1.25850	1.25545	1.25235	49	1.12600	1.12575	1.12360	1.12110	1.11845
98	1.25900	1.25865	1.25590	1.25290	1.24975	48	1.12325	1.12305	1.12090	1.11840	1.11580
97	1.25645	1.25610	1.25335	1.25030	1.24710	47	1.12055	1.12030	1.11820	1.11575	1.11320
96	1.25385	1.25350	1.25080	1.24770	1.24450	46	1.11780	1.11760	1.11550	1.11310	1.11055
95	1.25130	1.25095	1.24825	1.24515	1.24190	45	1.11510	1.11490	1.11280	1.11040	1.10795
94	1.24865	1.24830	1.24560	1.24250	1.23930	44	1.11235	1.11215	1.11010	1.10775	1.10530
93	1.24600	1.24565	1.24300	1.23985	1.23670	43	1.10960	1.10945	1.10740	1.10510	1.10265
92	1.24340	1.24305	1.24035	1.23725	1.23410	42	1.10690	1.10670	1.10470	1.10240	1.10005
91	1.24075	1.24040	1.23770	1.23460	1.23150	41	1.10415	1.10400	1.10200	1.09975	1.09740
90	1.23810	1.23775	1.23510	1.23200	1.22890	40	1.10145	1.10130	1.09930	1.09710	1.09475
89	1.23545	1.23510	1.23245	1.22935	1.22625	39	1.09875	1.09860	1.09665	1.09445	1.09215
88	1.23280	1.23245	1.22975	1.22665	1.22360	38	1.09605	1.09590	1.09400	1.09180	1.08955
87	1.23015	1.22980	1.22710	1.22400	1.22095	37	1.09340	1.09320	1.09135	1.08915	1.08690
86	1.22750	1.22710	1.22445	1.22135	1.21830	36	1.09070	1.09050	1.08865	1.08655	1.08430
85	1.22485	1.22445	1.22180	1.21870	1.21565	35	1.08800	1.08780	1.08600	1.08390	1.08165
84	1.22220	1.22180	1.21915	1.21605	1.21300	34	1.08530	1.08515	1.08335	1.08125	1.07905
83	1.21955	1.21915	1.21650	1.21340	1.21035	33	1.08265	1.08245	1.08070	1.07860	1.07645
82	1.21690	1.21650	1.21380	1.21075	1.20770	32	1.07995	1.07975	1.07800	1.07600	1.07380
81	1.21425	1.21385	1.21115	1.20810	1.20505	31	1.07725	1.07705	1.07535	1.07335	1.07120
80	1.21160	1.21120	1.20850	1.20545	1.20240	30	1.07455	1.07435	1.07270	1.07070	1.06855
79	1.20885	1.20845	1.20575	1.20275	1.19970	29	1.07195	1.07175	1.07010	1.06815	1.06605
78	1.20610	1.20570	1.20305	1.20005	1.19705	28	1.06935	1.06915	1.06755	1.06560	1.06355
77	1.20335	1.20300	1.20030	1.19735	1.19435	27	1.06670	1.06655	1.06495	1.06305	1.06105
76	1.20060	1.20025	1.19760	1.19465	1.19170	26	1.06410	1.06390	1.06240	1.06055	1.05855
75	1.19785	1.19750	1.19485	1.19195	1.18900	25	1.06150	1.06130	1.05980	1.05800	1.05605
74	1.19510	1.19480	1.19215	1.18925	1.18635	24	1.05885	1.05870	1.05720	1.05545	1.05350
73	1.19235	1.19205	1.18940	1.18650	1.18365	23	1.05625	1.05610	1.05465	1.05290	1.05100
72	1.18965	1.18930	1.18670	1.18380	1.18100	22	1.05365	1.05350	1.05205	1.05035	1.04850
71	1.18690	1.18655	1.18395	1.18110	1.17830	21	1.05100	1.05090	1.04950	1.04780	1.04600
70	1.18415	1.18385	1.18125	1.17840	1.17565	20	1.04840	1.04825	1.04690	1.04525	1.04350
69	1.18135	1.18105	1.17850	1.17565	1.17290	19	1.04590	1.04575	1.04440	1.04280	1.04105
68	1.17860	1.17830	1.17575	1.17295	1.17020	18	1.04335	1.04325	1.04195	1.04035	1.03860
67	1.17585	1.17555	1.17300	1.17020	1.16745	17	1.04085	1.04075	1.03945	1.03790	1.03615
66	1.17305	1.17275	1.17025	1.16745	1.16470	16	1.03835	1.03825	1.03695	1.03545	1.03370
65	1.17030	1.17000	1.16750	1.16475	1.16195	15	1.03580	1.03570	1.03450	1.03300	1.03130
64	1.16755	1.16725	1.16475	1.16200	1.15925	14	1.03330	1.03320	1.03200	1.03055	1.02885
63	1.16480	1.16445	1.16205	1.15925	1.15650	13	1.03080	1.03070	1.02955	1.02805	1.02640
62	1.16200	1.16170	1.15930	1.15655	1.15375	12	1.02830	1.02820	1.02705	1.02560	1.02395
61	1.15925	1.15895	1.15655	1.15380	1.15100	11	1.02575	1.02565	1.02455	1.02315	1.02150
60	1.15650	1.15615	1.15380	1.15105	1.14830	10	1.02325	1.02315	1.02210	1.02070	1.01905
59	1.15370	1.15340	1.15105	1.14835	1.14555	9	1.02085	1.02075	1.01970	1.01835	1.01670
58	1.15095	1.15065	1.14830	1.14560	1.14285	8	1.01840	1.01835	1.01730	1.01600	1.01440
57	1.14815	1.14785	1.14555	1.14285	1.14010	7	1.01600	1.01590	1.01495	1.01360	1.01205
56	1.14535	1.14510	1.14280	1.14015	1.13740	6	1.01360	1.01350	1.01255	1.01125	1.00970
55	1.14260	1.14230	1.14005	1.13740	1.13470	5	1.01120	1.01110	1.01015	1.00890	1.00735
54	1.13980	1.13955	1.13730	1.13465	1.13195	4	1.00875	1.00870	1.00780	1.00655	1.00505
53	1.13705	1.13680	1.13455	1.13195	1.12925	3	1.00635	1.00630	1.00540	1.00415	1.00270
52	1.13425	1.13400	1.13180	1.12920	1.12650	2	1.00395	1.00385	1.00300	1.00180	1.00035
51	1.13150	1.13125	1.12905	1.12650	1.12380	1	1.00155	1.00145	1.00060	0.99945	0.99800
						0	0.99913	0.99905	0.99823	0.99708	0.99568

Table 7.193: Freezing Points of Glycerol-Water Solutions *(23)*

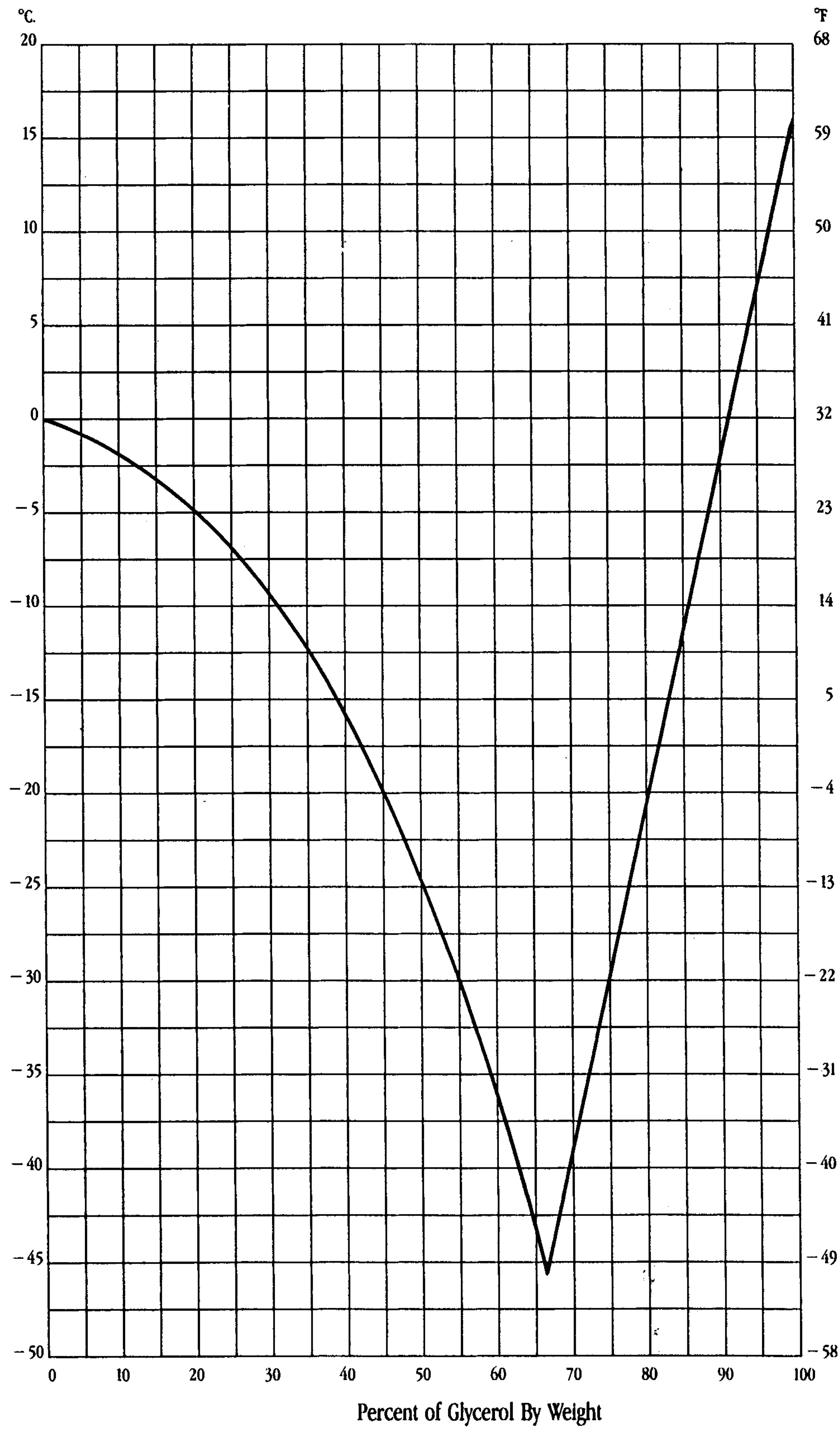


Table 7.194: Freezing Points of Glycerol-Water Solutions *(23)*

Glycerol by Wt. (%)	Water (%)	Freezing Points (°C)	Glycerol by Wt. (%)	Water (%)	Freezing Points (°C)
0.0[a]	100.0	0	65.0	35.0	−43.0
5.0	95.0	−0.6	65.6[b]	34.4	−44.5
10.0	90.0	−1.6	66.0[b]	34.0	−44.7
11.5[b]	88.5	−2.0	66.7[b]	33.3	−46.5
15.0	85.0	−3.1	67.1[b]	32.9	−45.5
20.0	80.0	−4.8	67.3[b]	32.7	−44.5
22.6[b]	77.4	−6.0	68.0[b]	32.0	−44.0
25.0	75.0	−7.0	70.0	30.0	−38.9
30.0	70.0	−9.5	70.9[b]	29.1	−37.5
33.3[b]	67.0	−11.0	75.0	25.0	−29.8
35.0	65.0	−12.2	75.4[b]	24.6	−28.5
40.0	60.0	−15.4	79.0[b]	21.0	−22.0
44.5[b]	55.5	−18.5	80	20.0	−20.3
45.0	55.0	−18.8	84.8[b]	15.2	−10.5
50.0	50.0	−23.0	85.0	15.0	−10.9
53.0[b]	47.0	−26.0	90.0	10.0	−1.6
55.0	45.0	−28.2	90.3[b]	9.7	−1.0
60.0	40.0	−34.7	95.0	5.0	7.7
60.4[b]	39.6	−35.0	95.3[b]	4.7	7.5
64.0[b]	36.0	−41.5	98.2[b]	1.8	13.5
64.7[b]	35.3	−42.5	100.0[a]	0.0	17.0

[a]Taken from literature.
[b]Actual determination.
Remaining values were interpolated from curve.

Table 7.195: Viscosity of Aqueous Glycerol Solutions Centipoises *(23)*

Glycerol % Wt.	Temperature (°C) 0	10	20	30	40	50	60	70	80	90	100
0*	1.792	1.308	1.005	0.8007	0.6560	0.5494	0.4688	0.4061	0.3565	0.3165	0.2838
10	2.44	1.74	1.31	1.03	0.826	0.680	0.575	0.500	–	–	–
20	3.44	2.41	1.76	1.35	1.07	0.879	0.731	0.635	–	–	–
30	5.14	3.49	2.50	1.87	1.46	1.16	0.956	0.816	0.690	–	–
40	8.25	5.37	3.72	2.72	2.07	1.62	1.30	1.09	0.918	0.763	0.668
50	14.6	9.01	6.00	4.21	3.10	2.37	1.86	1.53	1.25	1.05	0.910
60	29.9	17.4	10.8	7.19	5.08	3.76	2.85	2.29	1.84	1.52	1.28
65	45.7	25.3	15.2	9.85	6.80	4.89	3.66	2.91	2.28	1.86	1.55
67	55.5	29.9	17.7	11.3	7.73	5.50	4.09	3.23	2.50	2.03	1.68
70	76	38.8	22.5	14.1	9.40	6.61	4.86	3.78	2.90	2.34	1.93
75	132	65.2	35.5	21.2	13.6	9.25	6.61	5.01	3.80	3.00	2.43
80	255	116	60.1	33.9	20.8	13.6	9.42	6.94	5.13	4.03	3.18
85	540	223	109	58	33.5	21.2	14.2	10.0	7.28	5.52	4.24
90	1310	498	219	109	60.0	35.5	22.5	15.5	11.0	7.93	6.00
91	1590	592	259	127	68.1	39.8	25.1	17.1	11.9	8.62	6.40
92	1950	729	310	147	78.3	44.8	28.0	19.0	13.1	9.46	6.82
93	2400	860	367	172	89	51.5	31.6	21.2	14.4	10.3	7.54
94	2930	1040	437	202	105	58.4	35.4	23.6	15.8	11.2	8.19
95	3690	1270	523	237	121	67.0	39.9	26.4	17.5	12.4	9.08
96	4600	1580	624	281	142	77.8	45.4	29.7	19.6	13.6	10.1
97	5770	1950	765	340	166	88.9	51.9	33.6	21.9	15.1	10.9
98	7370	2460	939	409	196	104	59.8	38.5	24.8	17.0	12.2
99	9420	3090	1150	500	235	122	69.1	43.6	27.8	19.0	13.3
100	12070	3900	1410	612	284	142	81.3	50.6	31.9	21.3	14.8

*Viscosity of water taken from "Properties of Ordinary Water-Substance," N.E. Dorsey, p. 184. New York (1940)

Table 7.196: Hygroscopicity Curves for Glycerol and 1,3-Butylene Glycol *(42)*

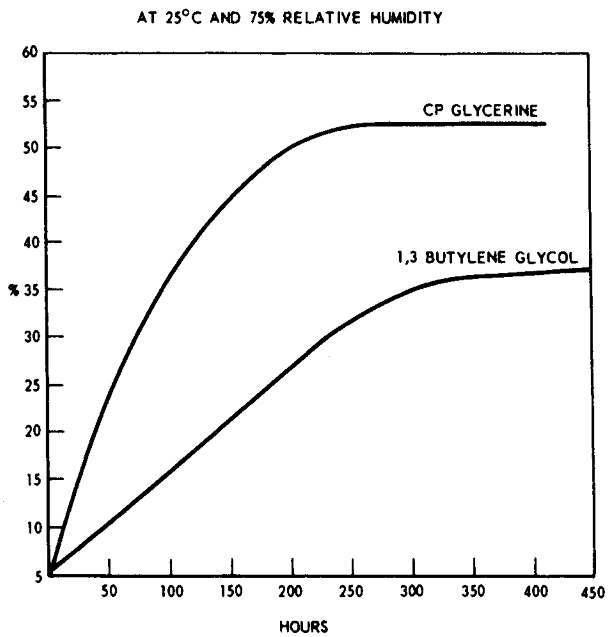


Table 7.197: Hygroscopicity Curves for Glycerol and 2,3-Butylene Glycol *(42)*

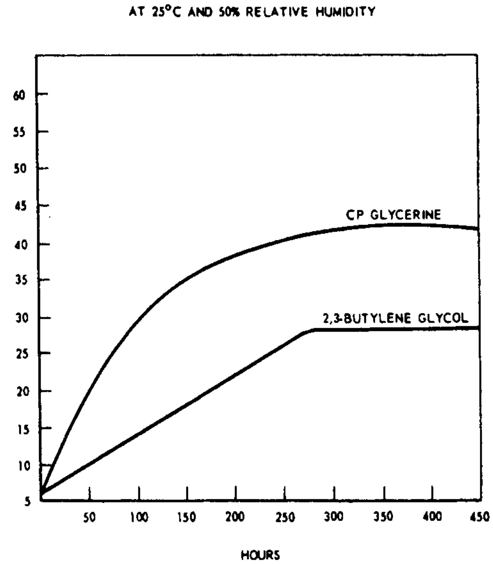


Table 7.198: Relative Humidities Over Aqueous Glycerol Solutions, 20° to 100°C *(23)*

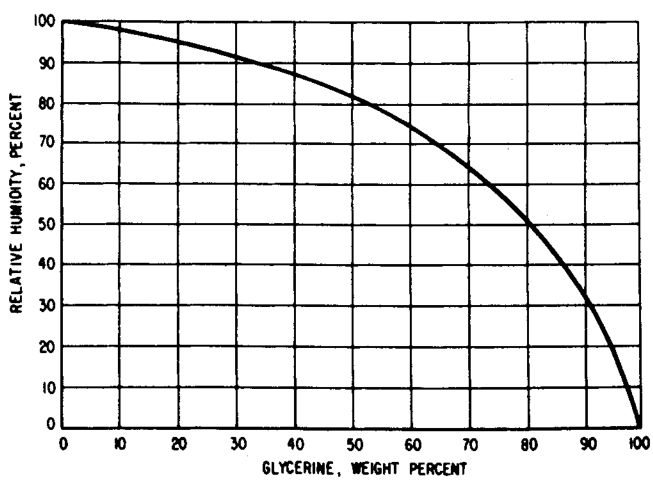


Table 7.199: Solubility of Sucrose and Dextrose in Aqueous Glycerol at 15°, 24°, and 35°C *(32)*

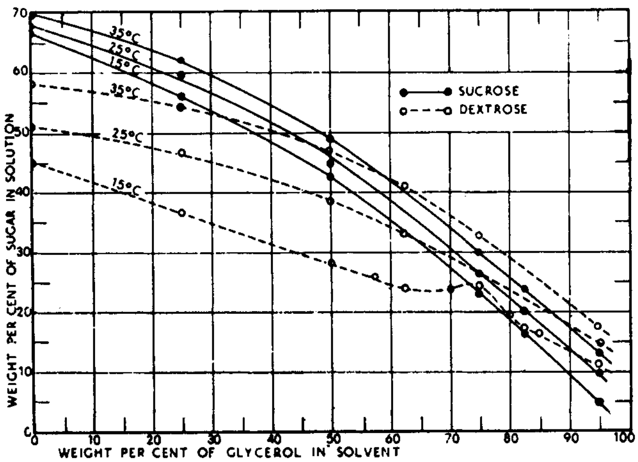


Table 7.200: Solubility of Various Compounds in Glycerol *(32)*

Substance	Glycerol Concentration % Weight	Temperature °C	Solubility in Parts per 100 Parts of Solvent
Alum	†	15	40
Ammonium carbonate	†	15	20
Ammonium chloride	†	15	20.06
Atropine	†	15	3
Benzoic acid	98.5	--	2
Boric acid	98.5	20	24.80
Calcium hydroxide	35	25	1.3
Calcium hypophosphite	99.04	20	2.5
Calcium sulfate	†	15	5.17
Codeine hydrochloride	99.04	20	11.1
Ethyl ether	99.04	20	0.65
Ferrous sulfate	†	15	25
Guaiacol	99.04	20	13.1
Iodine	†	15	2
Iodoform	95	15	0.12
Iron and potassium tartrate	†	15	8
Iron lactate	†	15	16
Morphine acetate	†	15	20
Novocaine	99.04	20	11.2
Phenacetin	99.04	20	0.47
Phenol	99.04	20	276.4
Potassium iodide	†	15	39.72
Quinine sulfate	98.5	--	1.32
Salicin	†	15	12.5
Sodium bicarbonate	†	15	8.06
Sodium carbonate (crystals)	†	15	98.3
Sodium tetraborate (borax)	†	15	60
Tannic acid	†	15	48.8
Tartar emetic	†	15	5.5
Urea	†	15	50
Zinc chloride	†	15	49.87
Zinc iodide	†	15	39.78

†Glycerol concentration not specified, probably 95 to 100 per cent.

Table 7.201: Specific Gravity and Percent Glycerol *(32)*

Glycerol	Apparent Specific Gravity				Glycerol	Apparent Specific Gravity			
	15/15° C	15.5/15.5° C	20/20° C	25/25° C		15/15° C	15.5/15.5° C	20/20° C	25/25° C
Per Cent					Per Cent				
100	1.26557	1.26532	1.26362	1.26201	50	1.12985	1.12970	1.12845	1.12720
99	1.26300	1.26275	1.26105	1.25945	49	1.12710	1.12695	1.12570	1.12450
98	1.26045	1.26020	1.25845	1.25685	48	1.12440	1.12425	1.12300	1.12185
97	1.25785	1.25760	1.25585	1.25425	47	1.12165	1.12150	1.12030	1.11915
96	1.25525	1.25500	1.25330	1.25165	46	1.11890	1.11880	1.11760	1.11650
95	1.25270	1.25245	1.25075	1.24910	45	1.11620	1.11605	1.11490	1.11380
94	1.25005	1.24980	1.24810	1.24645	44	1.11345	1.11335	1.11220	1.11115
93	1.24740	1.24715	1.24545	1.24380	43	1.11075	1.11060	1.10950	1.10845
92	1.24475	1.24450	1.24280	1.24115	42	1.10800	1.10790	1.10680	1.10575
91	1.24210	1.24185	1.24020	1.23850	41	1.10525	1.10515	1.10410	1.10310
90	1.23950	1.23920	1.23755	1.23585	40	1.10255	1.10245	1.10135	1.10040
89	1.23680	1.23655	1.23490	1.23320	39	1.09985	1.09975	1.09870	1.09775
88	1.23415	1.23390	1.23220	1.23055	38	1.09715	1.09705	1.09605	1.09510
87	1.23150	1.23120	1.22955	1.22790	37	1.09445	1.09435	1.09335	1.09245
86	1.22885	1.22855	1.22690	1.22520	36	1.09175	1.09165	1.09070	1.08980
85	1.22620	1.22590	1.22420	1.22255	35	1.08905	1.08895	1.08805	1.08715
84	1.22355	1.22325	1.22155	1.21990	34	1.08635	1.08625	1.08535	1.08455
83	1.22090	1.22055	1.21890	1.21720	33	1.08365	1.08355	1.08270	1.08190
82	1.21820	1.21790	1.21620	1.21455	32	1.08100	1.08085	1.08005	1.07925
81	1.21555	1.21525	1.21355	1.21190	31	1.07830	1.07815	1.07735	1.07660
80	1.21290	1.21260	1.21090	1.20925	30	1.07560	1.07545	1.07470	1.07395
79	1.21015	1.20985	1.20815	1.20655	29	1.07295	1.07285	1.07210	1.07135
78	1.20740	1.20710	1.20540	1.20380	28	1.07035	1.07025	1.06950	1.06880
77	1.20465	1.20440	1.20270	1.20110	27	1.06770	1.06760	1.06690	1.06625
76	1.20190	1.20165	1.19995	1.19840	26	1.06510	1.06500	1.06435	1.06370
75	1.19915	1.19890	1.19720	1.19565	25	1.06250	1.06240	1.06175	1.06115
74	1.19640	1.19615	1.19450	1.19295	24	1.05985	1.05980	1.05915	1.05860
73	1.19365	1.19340	1.19175	1.19025	23	1.05725	1.05715	1.05655	1.05605
72	1.19090	1.19070	1.18900	1.18755	22	1.05460	1.05455	1.05400	1.05350
71	1.18815	1.18795	1.18630	1.18480	21	1.05200	1.05195	1.05140	1.05095
70	1.18540	1.18520	1.18355	1.18210	20	1.04935	1.04935	1.04880	1.04840
69	1.18260	1.18240	1.18080	1.17935	19	1.04685	1.04680	1.04630	1.04590
68	1.17985	1.17965	1.17805	1.17660	18	1.04435	1.04430	1.04380	1.04345
67	1.17705	1.17685	1.17530	1.17385	17	1.04180	1.04180	1.04135	1.04100
66	1.17430	1.17410	1.17255	1.17110	16	1.03930	1.03925	1.03885	1.03850
65	1.17155	1.17130	1.16980	1.16835	15	1.03675	1.03675	1.03635	1.03605
64	1.16875	1.16855	1.16705	1.16560	14	1.03425	1.03420	1.03390	1.03360
63	1.16600	1.16575	1.16430	1.16285	13	1.03175	1.03170	1.03140	1.03110
62	1.16320	1.16300	1.16155	1.16010	12	1.02920	1.02920	1.02890	1.02865
61	1.16045	1.16020	1.15875	1.15735	11	1.02670	1.02665	1.02640	1.02620
60	1.15770	1.15745	1.15605	1.15460	10	1.02415	1.02415	1.02395	1.02370
59	1.15490	1.15465	1.15325	1.15185	9	1.02175	1.02175	1.02155	1.02135
58	1.15210	1.15190	1.15050	1.14915	8	1.01935	1.01930	1.01915	1.01900
57	1.14935	1.14910	1.14775	1.14640	7	1.01690	1.01690	1.01675	1.01660
56	1.14655	1.14635	1.14500	1.14365	6	1.01450	1.01450	1.01435	1.01425
55	1.14375	1.14355	1.14220	1.14090	5	1.01210	1.01205	1.01195	1.01185
54	1.14100	1.14080	1.13945	1.13815	4	1.00965	1.00965	1.00955	1.00950
53	1.13820	1.13800	1.13670	1.13540	3	1.00725	1.00725	1.00720	1.00710
52	1.13540	1.13525	1.13395	1.13265	2	1.00485	1.00485	1.00480	1.00475
51	1.13265	1.13245	1.13120	1.12995	1	1.00240	1.00240	1.00240	1.00235

Table 7.202: Specific Gravities of Glycerol and Glycol Mixtures *(23)*

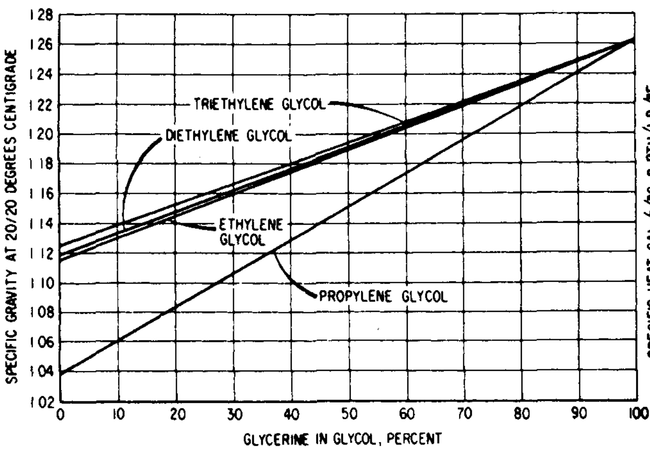


Table 7.203: Specific Heat of Glycerol *(23)*

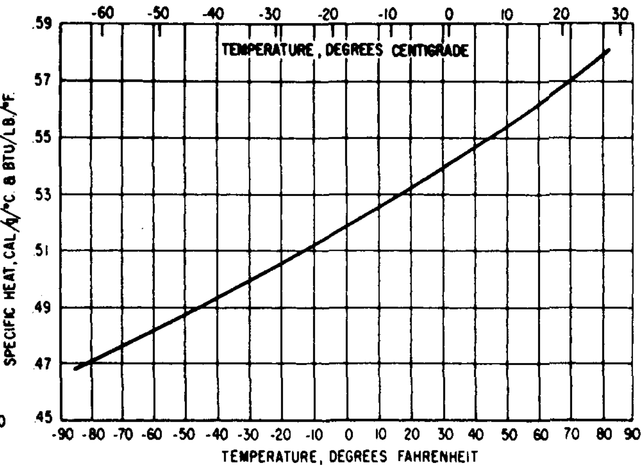


Table 7.204: Vapor Pressure of Glycerol *(23)*

Temperature, °C	V. P. mm. Hg.	Temperature, °C	V. P. mm. Hg.
120	--	210	63.8
130	1.47	220	91.9
140	2.61	230	130
150	4.48	240	181
160	7.44	250	248
170	12.0	260	334
180	18.9	270	445
190	29.0	280	586
200	43.4	290	760

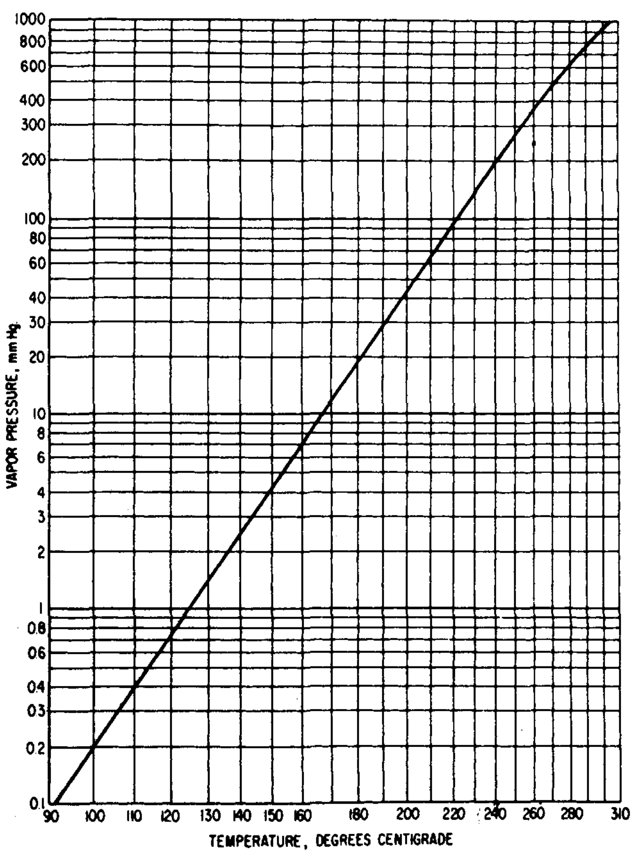


Table 7.205: Vapor Pressure of Glycerol-Water Solutions *(23)*

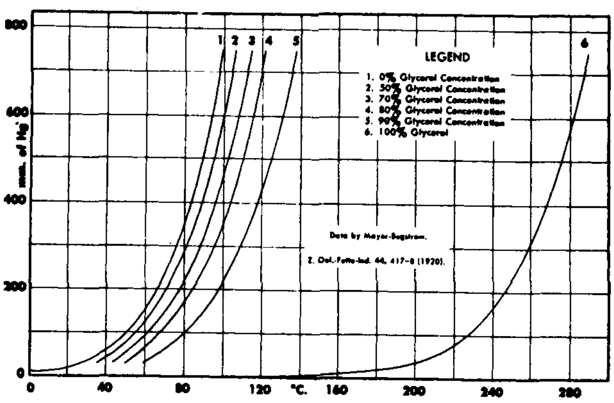
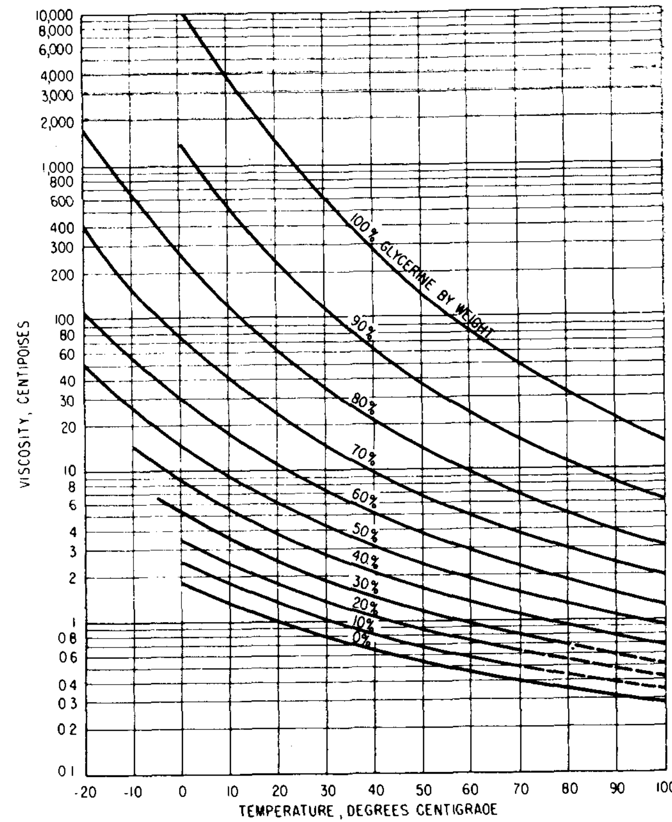


Table 7.206: Viscosity of Glycerol Solutions in Centipoises *(23)(32)*

Glycerol %	Temperature F.p.	-5°	-10°	-20°	-30°	-40°
10	-1.6°	---	---	---	---	---
20	-4.8°	---	---	---	---	---
30	-9.5°	6.5	---	---	---	---
40	-15.4°	10.3	14.4	---	---	---
50	-23.0°	18.8	24.4	48.1	---	---
60	-34.7°	41.6	59.1	108.0	244.0	---
66.7	-46.5°	74.7	113.0	289.0	631.0	1398.0
70	-38.5°	110.0	151.0	394.0	1046.0	---
80	-20.3°	419.0	683.0	1600.0	---	---
90	-1.6°	---	---	---	---	---

Glycerol % Wt.	Temperature °C. 0	10	20	30	40	50	60	70	80	90	100
0†	1.792	1.308	1.005	0.8007	0.6560	0.5494	0.4688	0.4061	0.3565	0.3165	0.2838
10	2.44	1.74	1.31	1.03	0.826	0.680	0.575	0.500	---	---	---
20	3.44	2.41	1.76	1.35	1.07	0.879	0.731	0.635	---	---	---
30	5.14	3.49	2.50	1.87	1.46	1.16	0.956	0.816	0.690	---	---
40	8.25	5.37	3.72	2.72	2.07	1.62	1.30	1.09	0.918	0.763	0.668
50	14.6	9.01	6.00	4.21	3.10	2.37	1.86	1.53	1.25	1.05	0.910
60	29.9	17.4	10.8	7.19	5.08	3.76	2.85	2.29	1.84	1.52	1.28
65	45.7	25.3	15.2	9.85	6.80	4.89	3.66	2.91	2.28	1.86	1.55
67	55.5	29.9	17.7	11.3	7.73	5.50	4.09	3.23	2.50	2.03	1.68
70	76.0	38.8	22.5	14.1	9.40	6.61	4.86	3.78	2.90	2.34	1.93
75	132.	65.2	35.5	21.2	13.6	9.25	6.61	5.01	3.80	3.00	2.43
80	255.	116.	60.1	33.9	20.8	13.6	9.42	6.94	5.13	4.03	3.18
85	540.	223.	109.	58.0	33.5	21.2	14.2	10.0	7.28	5.52	4.24
90	1310.	498.	219.	109.	60.0	35.5	22.5	15.5	11.0	7.93	6.00
91	1590.	592.	259.	127.	68.1	39.8	25.1	17.1	11.9	8.62	6.40
92	1950.	729.	310.	147.	78.3	44.8	28.0	19.0	13.1	9.46	6.82
93	2400.	860.	367.	172.	89.0	51.5	31.6	21.2	14.4	10.3	7.54
94	2930.	1040.	437.	202.	105.	58.4	35.4	23.6	15.8	11.2	8.19
95	3690.	1270.	523.	237.	121.	67.0	39.9	26.4	17.5	12.4	9.08
96	4600.	1580.	624.	281.	142.	77.8	45.4	29.7	19.6	13.6	10.1
97	5770.	1950.	765.	340.	166.	88.9	51.9	33.6	21.9	15.1	10.9
98	7370.	2460.	939.	409.	196.	104.	59.8	38.5	24.8	17.0	12.2
99	9420.	3090.	1150.	500.	235.	122.	69.1	43.6	27.8	19.0	13.3
100	12070.	3900.	1410.	612.	284.	142.	81.3	50.6	31.9	21.3	14.8

†Viscosity of water taken from Properties of Ordinary Water-Substances by N. E. Dorsey, New York, publisher 1940, p. 184.



COMPARATIVE DATA

Table 7.207: Emery CP/USP Glycerines *(63)*

	SPECIFICATIONS										
	Glycerol %, min.	Specific Gravity 25/25°C min.	Color APHA max.	Residue on Ignition PPM, max.	Chloride PPM max.	Sulfate PPM max.	Arsenic PPM max..	Heavy Metals PPM max.	Chlorinated Compounds PPM max.	Fatty Acids and Esters[2]	Readily Carbon-izable
EMERY® 912 96% CP/USP Glycerine	96.0	1.2517	20[1]	100	10	20	1.5	5	30	1.0	—[3]
EMERY® 916 99.7% CP/USP Glycerine	99.7	12612	10[1]	100	10	20	1.5	5	30	1.0	—[3]
EMERY® 917 99.7% CP/USP Kosher Glycerine	99.7	12612	10[1]	100	10	20	1.5	5	30	1.0	—[3]
EMERY® 918 99.8% CP/USP Ultra Glycerine	**99.8**	**1.2615**	**10**	**100**	**5**	**20**	**1.5**	**5**	**30**	**0.18**	**—[3]**

[1] *Meets USP specification which is equivalent to 20 APHA.*
[2] *Ml 0.5N NaOH per 50 g of glycerine.*
[3] *Lighter than matching H fluid*

Table 7.208: Proctor & Gamble Glycerine *(39)*

Glycerine (Ivorydale Production)

	Superol™ Glycerine-U.S.P. Food Grade	Star™ Glycerine-U.S.P. Food Grade
Glycerol (Bosart & Snoddy tables)	99.7% minimum (99.9)	96% minimum (96.3)
Specific Gravity, by density meter: at 25°/25°C (77°/77°F)	1.2613 minimum (1.2618)	1.2517 minimum (1.2524)
Color, APHA Pt-Co (Hazen) scale	10 maximum (6)	10 maximum (5)
Residue on ignition	0.007% or 70 ppm max	0.007% or 70 ppm max
Chlorides (as chlorine)	0.001% or 10 ppm max	0.001% or 10 ppm max
Sulfates	0.002% or 20 ppm max	0.002% or 20 ppm max
Arsenic (as As_1)	0.00015% or 1.5 ppm max	0.00015% or 1.5 ppm max
Heavy Metals (as Pb)	0.0005% or 5 ppm max	0.0005% or 5 ppm max
Chlorinated Compounds (as Cl)	0.003% or 30 ppm max	0.003% or 30 ppm max
Fatty Acids and Esters	Not more than 0.3 ml. N/2 NaOH is absorbed by 50 g of glycerine, which is equivalent to 0.009% as Na_2O, (0.13) maximum	Not more than 0.3 ml. N/2 NaOH is absorbed by 50 g of glycerine, which is equivalent to 0.009% as Na_2O, (0.12) maximum

Superol is also available in Kosher grade.
CAS No. 56-81-5, for both brands.

Table 7.209: Witco Refined Glycerine *(26)*

HYDROGENATED TRIGLYCERIDES

PRODUCT	DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: IODINE VALUE	ACID VALUE	SAP VALUE	% UNSAP MAX	COLOR MAX	MELTING POINT °C (TYPICAL)	TYPICAL CARBON CHAIN COMPOSITION: SATURATED C14	C16	C18	C20	C22	UNSATURATED C18:1	OTHERS
Neustrene 045	Hydrogenated Marine Triglycerides (Hydrogenated Menhaden Oil) **68424-59-9**	18-30	6	188-201	1	3 Gardner	47	8	34	18	11	5	17	7
Neustrene 053	Hydrogenated Marine Triglycerides (Hydrogenated Menhaden Oil) **68002-72-2**	5	5	186-201	1	3 Gardner	55	9	38	20	17	10		6
Neustrene 059	Hydrogenated Tallow Triglycerides (Hydrogenated Tallow Glycerides) **67701-27-3**	5	10	193-205	1	5 Gardner	61	2	28	67				3
Neustrene 060	Refined Hydrogenated Tallow Triglycerides (Hydrogenated Tallow Glycerides) **67701-27-3**	1	2.5	193-205	1	5.0Y-0.5R Lovibond	62	2	28	67				3
Neustrene 064*	Hydrogenated Soya Triglycerides (Hydrogenated Soybean Oil) **68002-71-1**	2	4	188-200	1	3 Gardner	66		11	88				1

* Also available in powder form.
Typical moisture levels are below 0.3%.

REFINED GLYCERINE

PRODUCT[1,2]	GLYCERINE DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS**: SPECIFIC GRAVITY 25/25°C, MIN	COLOR MAX	RESIDUE ON IGNITION ppm MAX	CHLORIDE 10 ppm MAX	SULFATE 20 ppm MAX	ARSENIC 1.5 ppm MAX	HEAVY METALS 5 ppm MAX	CHLORINATED COMPOUNDS 30 ppm MAX	% SAP EQUIVALENT MAX	FATTY ACIDS AND ESTERS***
Kemstrene 99.7% USP	99.7% USP (Glycerine) **56-61-5**	1.2612	10 APHA	70	Pass	Pass	Pass	Pass	Pass		Pass
Kemstrene 96.0% USP	96.0% USP (Glycerine) **56-81-5**	1.25165		70	Pass	Pass	Pass	Pass	Pass		Pass
Kemstrene High Gravity*	High Gravity (Glycerine) **56-81-5**	1.2587		700	100 ppm					0.05	Pass

[1] USP glycerine meets USP standard for volatile organic compounds.
[2] Witco only provides USP glycerine. Witco does not offer CP.
* As per Federal Specification O-G-491c.
** All tests run per U.S. Pharmacopoeia 23, 1995 edition.
*** 1.0 ml of 0.5N NaOH maximum is required to neutralize 50 grams of glycerine.

1,2,4-BUTANETRIOL

$HOCH_2CHOHCH_2CH_2OH$

Table 7.210: Physical Properties of 1,2,4-Butanetriol *(32)*

Boiling point at 760 mm. Hg	312° C*
0.17 mm. Hg	116° C
Fire point, Cleveland open cup	393° F
Flash point	343° F
Freezing point	Supercools (resistance to crystallization)
Refractive index at 25° C, n_D	1.473
Specific gravity, d/4	1.182
Viscosity at 25° C	1038 cs. (kinematic) 1227 cp.
Weight per gallon at 25° C	9.86 lb.

Purified 1,2,4-Butanetriol

Fire point, Cleveland open	387° F
Flash point, Cleveland open cup	332° F
Heat of combustion	555 kcal./mole
Heat of formation	165.1 kcal./mole (liquid) 157 kcal./mole (gas)
Heat of vaporization	14.0 kcal./mole
Specific gravity, d/4	1.184

*Decomposes before reaching boiling point at atmospheric pressure. This is an extrapolated value.

1,2,6-HEXANETRIOL

$HOCH_2CHOH(CH_2)_3CH_2OH$

Table 7.211: Physical Properties of 1,2,6-Hexanetriol *(32)*

Boiling point at 5 mm. Hg	178° C	Specific gravity at 20/20° C	1.1063
Coefficient of expansion at 20° C	0.00054/°C	Δ Sp. Gr./Δ t at 10 to 40° C	0.00059/°C
Flash point, open cup	375° F	Vapor pressure at 20° C	Less than 0.01 mm. Hg
Freezing point	-32.8° C (freezes under controlled conditions; usually sets to glass at below -20° C)	Viscosity at 20° C	2584 cp.
		Weight per gallon at 20° C	9.19 lb.
Molecular weight	134.17	Δ lb./gal./Δ t	0.00499° C
Refractive index	1.4771		

Table 7.212: Freezing Points of 1,2,6-Hexanetriol-Water Mixtures *(32)*

(I) Observed
(II) Theoretical, without hydration
(III) Theoretical, with complete hydration

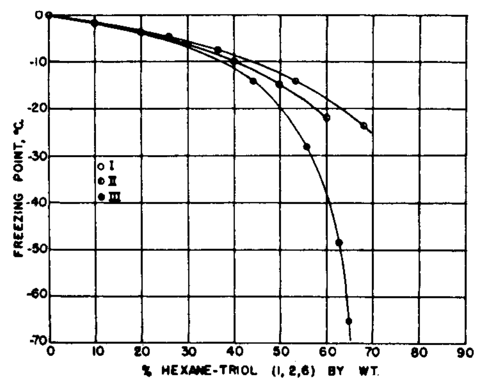


Table 7.213: Vapor Pressure of 1,2,6-Hexanetriol *(19)*

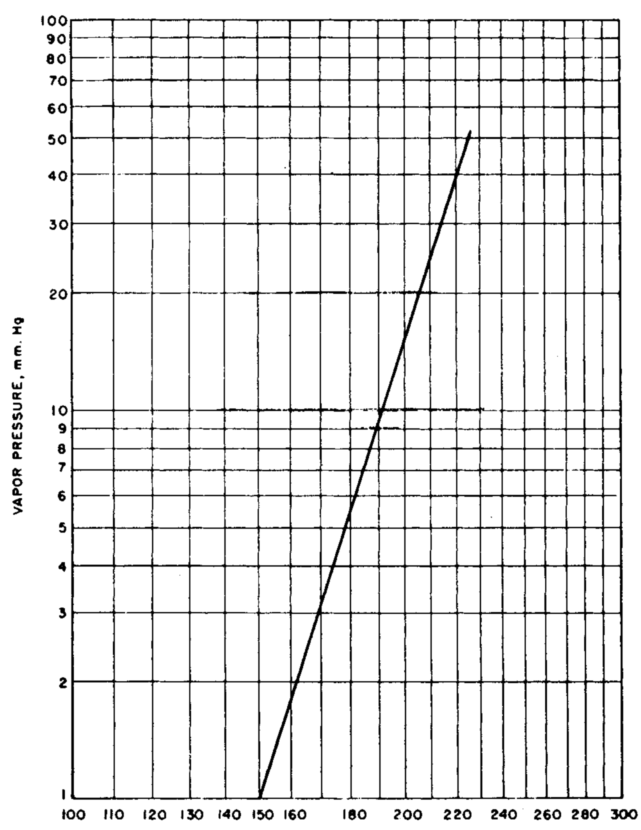


Table 7.214: Solubility of 1,2,6-Hexanetriol in Organic Solvents *(32)*

4cc. solvent and 1cc. triol at 20°C.

Acetone	M	Ethyl Acetate	I
Benzene	I	Ethyl Alcohol (Absolute)	M
Butanol	M	Ethyl Ether	I
Butyl Acetate	I	Heptane	I
Butyl CELLOSOLVE	M	Isophorone	M
Castor Oil	I	Methyl Isobutyl Ketone	I
CELLOSOLVE Acetate	I	Mineral Oil	I
CELLOSOLVE Solvent	M	Pine Oil	M
Diacetone Alcohol	M	Toluene	I
Dibutyl Phthalate	I	Trichlorethylene	I
Dichlorethyl Ether	I		

M = Miscible I = Immiscible

Table 7.215: Compatibility of 1,2,6-Hexanetriol *(32)*

4 parts material to 1 part triol

Animal Glue	C	Gelatin	PC
Beeswax	I	Nitrocellulose	I
Carnauba Wax No. 3	I	Paraffin Wax	I
Casein	C	Rosin	I
Ester Gum C	I	Shellac	PC
Ethyl Cellulose	I	Zein	C

C = Compatible I = Incompatible PC = Partly Compatible

Table 7.216: Viscosities and Freezing Points of 1,2,6-Hexanetriol *(32)*

1,2,6-Hexanetriol, % by wt. in H_2O	Viscosity, in cps. at 100°F.	Freezing Point °C.
10	0.977	-2.5
20	1.37	-4.5
30	2.01	-7.0
50	5.06	-15.5

TRIMETHYLOLPROPANE

2,2-Dihydroxymethyl-1-Butanol
Ethyl Trimethylolmethane
TMP

$C_2H_5C(CH_2OH)_3$

Table 7.217: Physical Properties of Trimethylolpropane *(32)*

Acidity as formic acid	0.002% by wt., max.
Ash	0.01% by wt., min.
Boiling point at 5 mm. Hg abs.	160° C
50 mm. Hg abs.	210° C
760 mm. Hg (extrapolated)	295° C
Bulk density (free-flowing)	35.5 lb/ft^3
Color of 10% aqueous solution	5 Pt-Co units, max.
Combining weight	44.72
Fire point, Cleveland open cup	380° F
Flash point, Cleveland open cup	355° F
Freezing point	59° C
Hydroxyl content	37.5% by wt., min.
Hygroscopicity (water absorbed in 68 hrs.):	
at 27° C and 18 to 26% RH	0.00% by wt.
at 25° C and 29 to 44% RH	0.06% by wt.
at 27° C and 70 to 80% RH	0.23% by wt.
Melting point range	57 to 59° C
Molecular weight	134.18
Phthalic color, Gardner	1 max.
Water content as packaged	0.05% by wt., max.

PENTAERYTHRITOL

Tetramethylolmethane
PE

$$\begin{array}{c} CH_2OH \\ | \\ HOH_2C - C - CH_2OH \\ | \\ CH_2OH \end{array}$$

Table 7.218: Physical Properties of Pentaerythritol *(32)*

Ash	0.01% by wt., max.
Bulk density	40 lb./ft.^{3}
Dipentaerythritol (combined)	0.3%
Hydroxyl content	47.0% min. (technical)
	49.5% (pure)
Melting point (capillary final)	240° C
	250° C initial (pure)
Melting point range	185-245° C (technical)
Moisture	0.40% by wt. (technical)
	0.10% by wt. (pure)
Molecular weight	136.1
Monopentaerythritol	88.0% by wt. (technical)
	97.0% by wt. (pure)
Nonvolatile	99.50% min.
Specific gravity at 25/4° C	1.38

SORBITOL

d-Sorbitol
Sorbit
Sorbol
d-Glucitol

$CH_2OH(CHOH)_4CH_2OH$

Table 7.219: Physical Properties of Sorbitol *(38)*

Density at -5° C	1.472
Heat of combustion	3994 cal./gm.
Negative heat of solution	-26.5 cal./gm.
Molecular weight	182.17
Melting point, metastable form	93° C
stable form	97.7° C
Refractive index at 25° C, in 10% aqueous solution	1.3477
Rotation, $^{25}_{D}$	-0.985° C

Table 7.220: Boiling Point of Sorbitol Solutions *(38)*

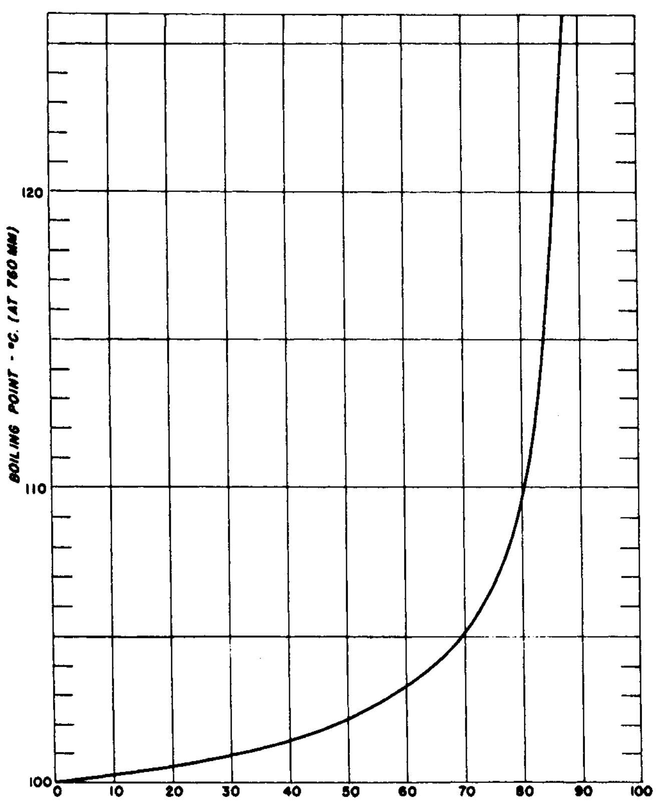


Table 7.221: Hydrogenolysis of Sorbitol and Glycerol at a Hydrogen Pressure of 2,000 psi *(32)*

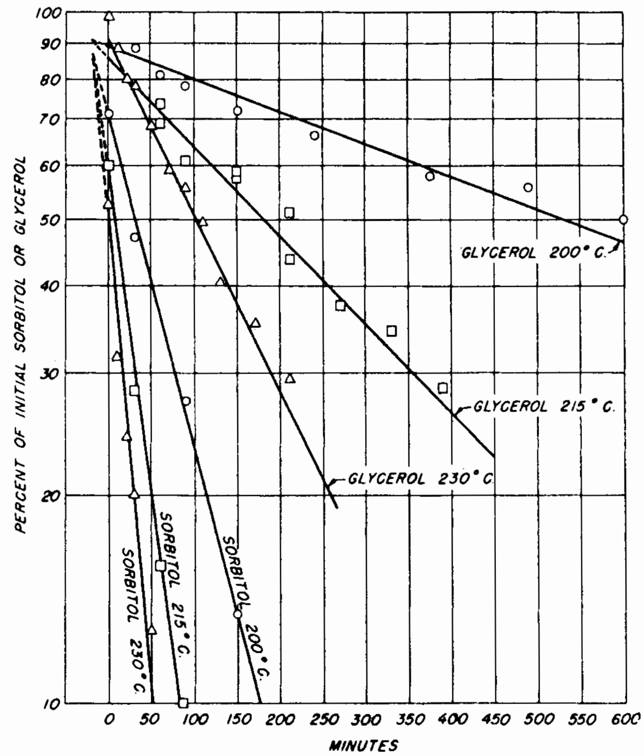


Table 7.222: Hydrogenolysis of Sorbitol at 215°C and a Hydrogen Pressure of 2,000 psi *(32)*

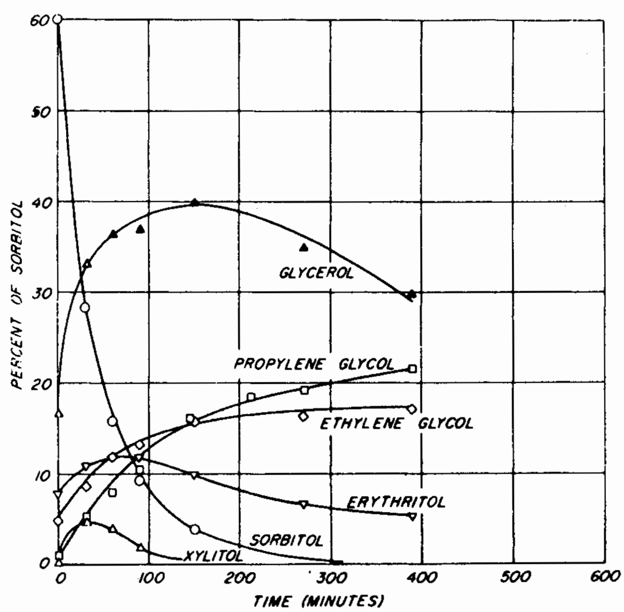


Table 7.223: Phase Diagram of Sorbitol Solubility in Hydroalcoholic Liquids at 25°C *(38)*

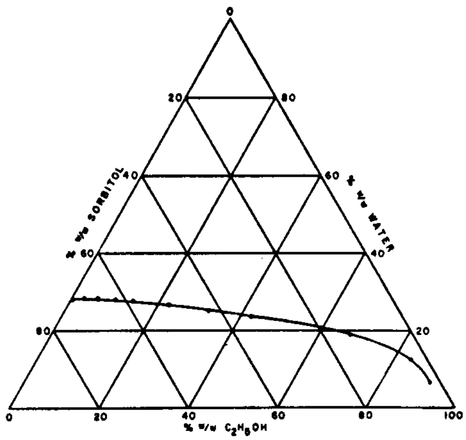


Table 7.224: Solubility of Sorbitol in Hydroalcoholic Liquids at 25°C *(38)*

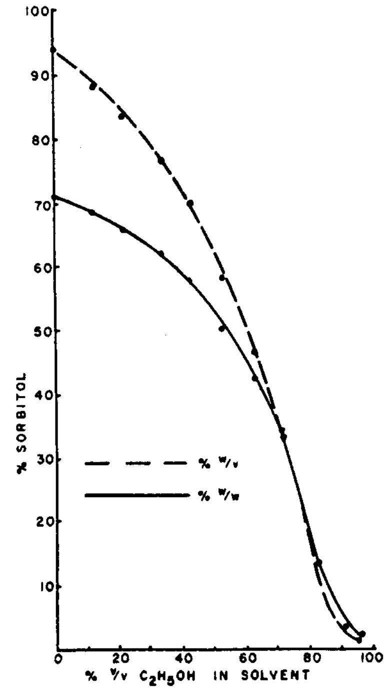
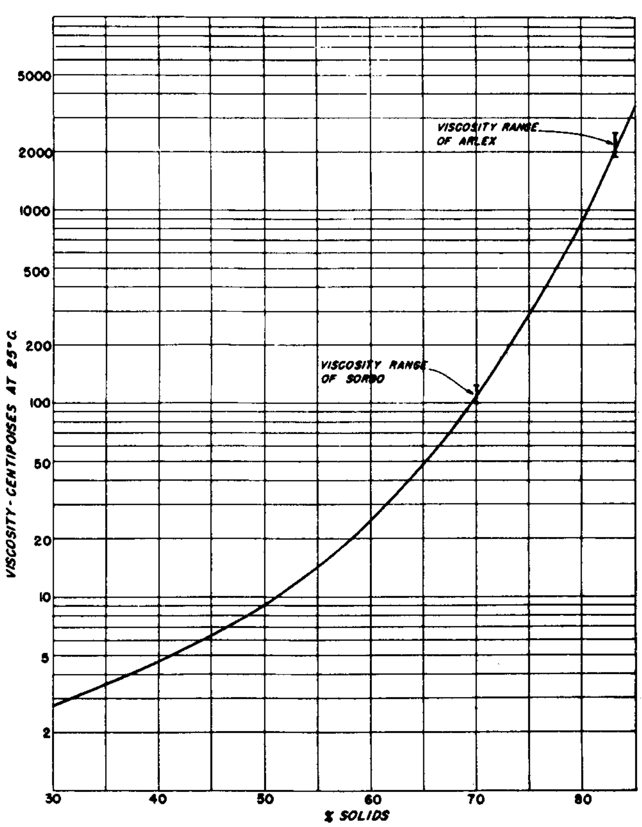


Table 7.225: Viscosity Curve for Pure d-Sorbitol Solutions of Various Concentrations *(38)*



SUGAR ALCOHOLS

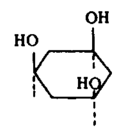
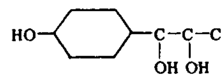
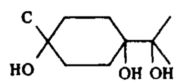
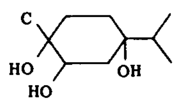
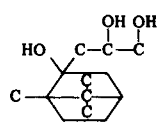
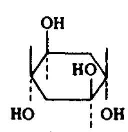
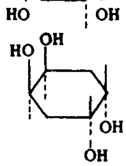
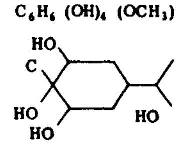
Table 7.226: Physical Properties of the Sugar Alcohols *(38)*

Sugar alcohol	Melting point, °C	Optical activity in H_2O, $[\alpha]_D^{20-25}$	Solubility, g/100 g H_2O[c]	Heat of combustion, constant volume, kcal/mole
tetritols				
erythritol	120	meso	61.5	499.9 (94)
D-threitol	88.5-90	+4.3	very soluble	
L-threitol	88.5-90	−4.3		
D,L-threitol	69-70			
pentitols				
ribitol	102	meso	very soluble	
xylitol	61-61.5 (metastable) 93-94.5 (stable)	meso	179	
D-arabitol	103	+131[a]	very soluble	
L-arabitol	102-103	−130[a]		611.7 (124)
hexitols				
allitol	155	meso	very soluble	
dulcitol	189	meso	3.2 (15° C)	720.3 (94)
sorbitol (D-glucitol)	90.4-91.8 (metastable)			
	96.7-97.7 (stable)	−1.98	235	723.5 (6)
L-glucitol	89-91	+1.7		
D,L-glucitol	135-137			
D-mannitol	166	−0.2	21.3	722.1 (6)
L-mannitol	162-163			
D,L-mannitol	168			
D-talitol	88-89	+3.2	very soluble	
L-talitol	87-88	−2.9		
D,L-talitol	95-96			
D-iditol	73.5	+3.5		
L-iditol	75.7-76.7	−3.5		
heptitols				
glycero-gulo-heptitol	129	meso	very soluble	
D-*glycero*-D-*ido*-heptitol	129	+0.7	very soluble	
perseitol	187	−1.1	7.4 (18° C)	835.8 (124)
volemitol	153	+2.15	22.2 (14° C)	
octitol				
D-*erythro*-D-*galacto*-octitol	169-170	−11[b]		

[a] In aqueous molybdic acid (46).
[b] In 5% aqueous ammonium molybdate (27).
[c] At 25°C unless otherwise indicated.

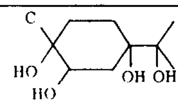
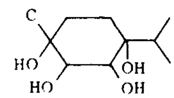
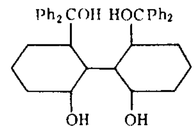
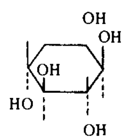
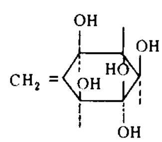
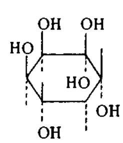
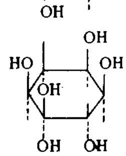
MISCELLANEOUS POLYHYDRIC ALCOHOLS

Table 7.227: Hydrates of Polyhydric Alcohols *(32)*

Alcohol				Hydrate	
Number of C Atoms	Name	Skeletal Structural Formula	M.p. (°C)	M.p. (°C)	n in $R(OH)_n \cdot nH_2O$
A. Trihydric Alcohols					
6	α (or cis)-Phloroglucitol		185	115	2
9	4(1,2-Dihydroxy-n-propyl)-cyclohexanol		63	31	3
10	p-Menthane-1,4,8-triol		110-112	96	1
10	p-Menthane-1,2,4-triol		129	115	---
10	Glycol (a dihydroxyether?)	$C_{10}H_{18}O_3$	103-105	---	1
13	2(2,3-Dihydroxy-n-propyl)-2-hydroxy camphane		---	---	---
B. Tetrahydric Alcohols					
6	cycloHexane-1,2,4,5-tetrol		---	195	1
6	cycloHexane-1,2,4,5-tetrol	 ?	242	---	2
8	A dimethylether of an inositol	$C_6H_6(OH)_4(OCH_3)_2$	230	--	3
10	trans(?)-p-Menthane-1,2,6,8-tetrol		156	100-105	2

(continued)

Table 7.227: (continued)

Alcohol				Hydrate	
Number of C Atoms	Name	Skeletal Structural Formula	M. p. (°C)	M. p. (°C)	n in $R(OH)_m \cdot nH_2O$
10	p-Menthane-1,2,4,8-tetrol		149	100	1
10	p-Menthane-1,2,3,4-tetrol		130	---	1
38	2,2'-Dihydroxy-6,6'-bis (α-hydroxybenz-hydryl)-diphenyl		308	141-145	2
C. Pentahydric Alcohols					
6	Viburnitol (cyclohexane-2,3,5/4,6-pentol)		181	---	1
6	Inositol bromo-hydrin	$C_6H_6(OH)_5Br$	170-5	---	1
6	Inositol chloro-hydrin	$C_6H_6(OH)_5Cl$	180-5	---	2
6	Scyllitol chloro-hydrin	$C_6H_6(OH)_5Cl$	---	---	2
7	1-Methylene-cyclohexane-2,4,6/3,5-pentol		205	---	2
D. Hexahydric Alcohols					
6	(+)-Sorbitol	$HOH_2C(CHOH)_4CH_2OH$	111	55 75	1 0.5
6	meso-Inositol (1,2,3,5/4,6-cyclohexane-hexol)		225	---	2
6	d- and l-Inositols (active) (1,3,4/2,5,6-cyclohexane-hexol)		248	---	2

Phenols

Table 8.1: Phenol *(2)*

Carbolic Acid C_6H_5OH

PHYSICAL PROPERTIES OF PHENOL

Boiling point	181.6°C
Distillation range	95% distills within a range of 1.5°C
Flash point (Open cup)	175°F
Freezing point	Not less than 40°C
MAC	5 ppm in air
Odor	Characteristic
Purity	98%, min.
Solidifying point	Not less than 40.7°C
Solubility in water, above 68°C at 20°C	In all proportions 8.3%
Specific gravity at 41/4°C	1.058
Toxicity	Highly toxic

PHENOL FORMS BINARY AZEOTROPES WITH

%		B.P. of Azeotrope °C.
92.2	Acetophenone	202.0
22	Amyl ether	180.2
58	Aniline	186.2
49	Benzaldehyde	185.5
55	Benzylamine	196.8
57	m-Bromotoluene	175.7
60	o-Bromotoluene	174.4
37	2-Butoxyethanol	186.4
54	Butylbenzene	175.0
30	Butyl isovalerate	184.0
78	Camphene	156.1
97	o-Chlorotoluene	159.0
28	Cineole	182.9
13	Cyclohexanol	183.0
28	Cyclohexanone	184.5
65	Decane	168.0
59	Ethyl oxalate	189.5
75	Fenchone	196.2
60	Glycol diacetate	189.9
28	Heptyl alcohol	185.0
55	Indene	173.2
85	Isoamyl ether	172.2
74	Isobutyl carbonate	192.5
17	Isopropyl lactate	184.8
79	Mesitylene	163.5
20	2-Methylcyclohexanol	183.1
77	Methyl fumarate	194.9
33	Methylheptenone	184.6
32	2-Octanone	184.5
87	n-Octyl alcohol	195.4
50	sec-Octyl alcohol	184.5
65	α-Phellandrene	165.0
82	Phorone	198.8
29	Pinacol	185.5
81	α-Pinene	152.8
75	Pseudocumene	166.0
55	Terpinene	171.5
60	Thymene	172.3

Aldehydes

FURFURAL

Furfuraldehyde
Furol
Pyromucic Aldehyde

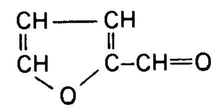


Table 9.1: Properties of Pure Furfural *(46)*

Furfural (2-furaldehyde), C_4H_3OCHO, is a liquid aldehyde with a pungent almond-like odor. Colorless when freshly distilled, it darkens on contact with air. Industrial furfural is light yellow to brown in color.

General	
Molecular weight	96.08
Boiling point (at 760 mm), °C (°F)	161.7 (323.06)
Freezing point, °C (°F)	−36.5 (−33.7)
Refractive index (n t/D)	
at 20° C (68° F)	1.5261
at 25° C (77° F)	1.5235
Density (d t/4)	
at 20° C (68° F)	1.1598
at 25° C (77° F)	1.1545
Vapor pressure	See Table 9.7
Vapor density (air=1)	3.3
Thermodynamic properties	
Heat of vaporization, ΔH_v g cal/g mole	11,614.6
Specific heat (liquid), cal/g/deg	
14 to 80° C (57.2 to 176° F)	0.401
20 to 100° C (68 to 212° F)	0.416
Thermal conductivity,	
Btu/(hr) (ft²) (°F/ft) at 100° F	0.1525
cal/(sec) (cm²) (°C/cm) at 38° C	6.3×10^{-4}
Heat of combustion (liquid), $\Delta H_{298.2}$ kcal/mole	−560.3
Fluid properties	
Viscosity, cps, at 0° C (32° F)	2.48
at 25° C (77° F)	1.49
at 38° C (100.4° F)	1.35
at 54° C (129.2° F)	1.09
at 99° C (210.2° F)	0.68
Surface tension, dynes/cm	
at 0° C (32° F)	43.5
at 29.9° C (85.9° F)	40.7
at 30.0° C (86° F)	41.1
Vapor diffusion coefficient, cm²/sec	
at 17° C (62.6° F)	0.076
at 25° C (77° F)	0.087
at 50° C (122° F)	0.107

(continued)

Table 9.1: (continued)

Electrical properties	
Dielectric constant	
at 1° C (33.8° F)	46.9
at 20° C (68° F)	41.9
at 25° C (77° F)	38
at 50° C (122° F)	34.9
Specific conductivity, mho	
Minimum	0.26×10^{-5}
Maximum	0.37×10^{-5}
Other properties	
Critical pressure, psia	798
kg/cm²	56.1
Critical temperature, ° C (° F)	397 (746.6)
Molar volume, 25° C, ml/mole	83.19
Molecular association	1.11
Solubility in	
water, wt. % at 20° C (68° F)	8.3
alcohol	∞
ether	∞

Note: Furfural is miscible with most common organic solvents except saturated aliphatic hydrocarbons.

Flammability properties	
Explosive limits (% by vol.)	
Lower limit (at 125° C [257° F] and 740 mm Hg)	2.1
Flash point	
Tag closed cup, °C (°F)	61.7 (143)
Pensky-Martens, °C (°F)	61.7 (143)
(Based on flash point, furfural is classified as Class III A.*)	
Ignition temperature, °C (°F)	393 (739)

Note:

Furfural has a high order of thermal stability in the absence of oxygen. At temperatures as high as 230° C (446° F), exposure for many hours is required to produce detectable changes in the physical properties of furfural, with the exception of color (29).

*Refers to Code of Federal Regulations: 29CFR 1910.106.

Table 9.2: Typical Properties and Specifications of Furfural *(2)*

Acidity, as acetic	Technical 0.3% Refined 0.1%
Boiling point	158–162°C
Density at 60°F	1.164
100°	1.140
150°	1.110
175°	1.095
200°	1.080
250°	1.049
300°	1.019
Distillation range (Engler)	
1%, °F (min.)	300
End point, °F (max.)	335
Recovery, % (min.)	98.5
Residue, % (max.)	0.9
Loss, % (max.)	0.9
Explosive limit, lower	2.1% at 257°F
Flash Point (Cleveland Open Cup)	131-5°F
Freezing point	−34°F
Heat of Vaporization	107.51 cal./g
Purity	98.5% Technical 99.0–99.5% Refined
Refractive index at 68°F	1.5261
Solubility in water at 20°C	8.3%
Specific gravity at 20/20°C	1.161 1.158–1.160 Technical 1.59–1.161 Refined
Surface tension	49 dynes/cm.
Vapor pressure at 60°F	0.035 lbs./sq. in. abs.
100°	0.130 lbs./sq. in. abs.
150°	0.540 lbs./sq. in. abs.
175°	0.950 lbs./sq. in. abs.
200°	1.650 lbs./sq. in. abs.
250°	4.40 lbs./sq. in. abs.
300°	11.50 lbs./sq. in. abs.
350°	22.50 lbs./sq. in. abs.
400°	43.5 lbs./sq. in. abs.
450°	77.0 lbs./sq. in. abs.
Viscosity at 100°F	1.35 centipoises
130°	1.09 centipoises
210°	0.68 centipoises
Weight per gallon (20°C)	9 lbs.

Table 9.3: Solubility of Various Substances in Furfural *(46)*

Acetone	S
Acids:	
Abietic (technical)	9.4
Acetic	S
Benzoic	14.8
Butyric (technical)	S
Cinnamic	4.1
Citric	3.6
Formic	S
Lactic	S
Maleic	R
Naphthenic acids (practical)	S
Oleic (U.S.P.)	S
Oxalic	4.8
Oxalic (anhydrous)	3.6
Palmitic (technical)	1.6
Phthalic	17.6
Propionic (technical)	S
Salicylic	11.0
Sebacic (mp 132-133° C [269.6-271.4° F])	0.8
Stearic (U.S.P.)	2.1
Succinic	3.0
Tartaric	10.9
Alcohols:	
Amyl	M
n-Butyl	S
Ethylene glycol	S
Glycerol	2.1-2.8
Isobutyl	S
n-Octyl	S
Amyl acetate	M
Benzene	S
Butyl acetate	M
Carbon tetrachloride	S
Castor oil	M
Chinawood oil	M
Chloroform	S
Diethylene glycol monobutyl ether	M
Diethylene glycol monoethyl ether	M
Diethyl phthalate	M
Ethyl acetate	S
Ethylene glycol	S
Ethylene glycol monobutyl ether	M
Ethylene glycol monoethyl ether	M
Ferric chloride	0.55
Ferric chloride hexahydrate	20.0
Hydrogen cyanide	M
Linseed oil	M
Nitrobenzene	M
Nitrotoluene	M
Paraldehyde	M
Pyridine	S
Quinoline	S
Toluene	S
Xylol	M
Zinc chloride	20.6

S=infinitely soluble
M=miscible in equal volume at room temperature
R=reaction

Table 9.4: Solubility of Selected Thermoplastic Resins in Furfural *(46)*

(At 23°C [73.4° F])

RESIN TYPE	MANUFACTURER	SOLVENT ACTION
Nitrocellulose	Hercules (RS)	VS
Ethylcellulose	Hercules (N-50)	VS
Cellulose acetate butyrate	Eastman	VS
Polyvinyl butyral	Union Carbide (Bakelite®)	S;VSH
Vinyl acetate	Union Carbide (Bakelite®)	SH (B)
Vinyl acetate chloride	Union Carbide (Bakelite®)	SH (B)
PVC	Uniroyal (Marvinol® VR-10)	1
PVC	Goodrich (Geon® 222)	SH
Nylon	Du Pont (Zytel® 31)	1 (B)
Nylon	Du Pont (Elvamide)	1 (B)
Polyethylene	Du Pont (Alathon®)	1 (B)
Acrylic	Du Pont (Lucite® 140)	SH (B)
Acrylic	Du Pont (Lucite® 130)	VS
Polystyrene	Dow (PS-3)	SH

S=Soluble from 1 g to 10 g per 100 g solvent
VS=Soluble 10 g or more per 100 g solvent
H=Temperature, 70-75° C (158-167° F); time one hour
B=Cloudy
1=Less than 1 g per 100 g solvent

Table 9.5: Specific Gravity and Pounds per Gallon of Furfural *(46)*

(Change per°C: Sp. Gr. –0.00110; lbs./gal. –0.00917)

TEMPERATURE °F	°C	SP. GR.[1]	LBS./GAL.	TEMPERATURE °F	°C	SP. GR.[1]	LBS./GAL.
122.0	50	1.127	9.403	57.2	14	1.167	9.733
118.4	48	1.129	9.421	53.6	12	1.169	9.752
114.8	46	1.131	9.440	50.0	10	1.171	9.770
111.2	44	1.134	9.458	46.4	8	1.173	9.788
107.6	42	1.136	9.476	42.8	6	1.175	9.807
104.0	40	1.138	9.494	39.2	4	1.178	9.825
100.4	38	1.140	9.502	35.6	2	1.180	9.833
96.8	36	1.142	9.531	32.0	0	1.182	9.861
93.2	34	1.145	9.549	28.4	– 2	1.184	9.879
89.6	32	1.147	9.568	24.8	– 4	1.186	9.898
86.0	30	1.149	9.586	21.2	– 6	1.189	9.916
82.4	28	1.151	9.604	17.6	– 8	1.191	9.935
78.8	26	1.153	9.623	14.0	–10	1.193	9.953
75.2	24	1.156	9.631	10.4	–12	1.195	9.971
71.6	22	1.158	9.660	6.8	–14	1.197	9.990
68.0	20	1.160	9.678	3.2	–16	1.200	10.008
64.4	18	1.162	9.696	–1.6	–18	1.202	10.027
60.8	16	1.164	9.715	–4.0	–20	1.204	10.045

[1] Referred to water at 4°C.

Table 9.6: Composition/Density of Furfural-Water Solutions[1] *(46)*

FURFURAL (% BY WEIGHT)	DENSITY $\frac{t°}{4}$ 20° C	DENSITY $\frac{t°}{4}$ 25° C	FURFURAL (% BY WEIGHT)	DENSITY $\frac{t°}{4}$ 20° C	DENSITY $\frac{t°}{4}$ 25° C
0	0.9982	0.9971	4.6	1.0068	1.0054
0.2	0.9986	0.9974	4.8	1.0072	1.0058
0.4	0.9990	0.9978	5.0	1.0075	1.0062
0.6	0.9993	0.9982	5.2	1.0079	1.0065
0.8	0.9997	0.9985	5.4	1.0083	1.0069
1.0	1.0001	0.9989	5.6	1.0086	1.0073
1.2	1.0005	0.9993	5.8	1.0090	1.0076
1.4	1.0008	0.9996	6.0	1.0094	1.0080
1.6	1.0012	1.0000	6.2	1.0098	1.0084
1.8	1.0016	1.0003	6.4	1.0101	1.0087
2.0	1.0020	1.0007	6.6	1.0105	1.0091
2.2	1.0023	1.0011	6.8	1.0109	1.0094
2.4	1.0027	1.0014	7.0	1.0113	1.0098
2.6	1.0031	1.0018	7.2	1.0116	1.0102
2.8	1.0034	1.0022	7.4	1.0120	1.0105
3.0	1.0038	1.0025	7.6	1.0124	1.0109
3.2	1.0042	1.0029	7.8	1.0127	1.0113
3.4	1.0046	1.0033	8.0	1.0131	1.0116
3.6	1.0049	1.0036	8.2	1.0135	1.0120
3.8	1.0053	1.0040	8.3[2]	1.0137	1.0122
4.0	1.0057	1.0044	8.4	—	1.0124
4.2	1.0060	1.0047	8.6[3]	—	1.0127
4.4	1.0064	1.0051			

[1] Mains, G.H., Chem. & Met. Eng., 26,779 (1922).
[2] Saturated solution of furfural in water at 20°C (68°F).
[3] Saturated solution of furfural in water at 25°C (77°F).

Table 9.7: Vapor Pressure of Furfural *(46)*

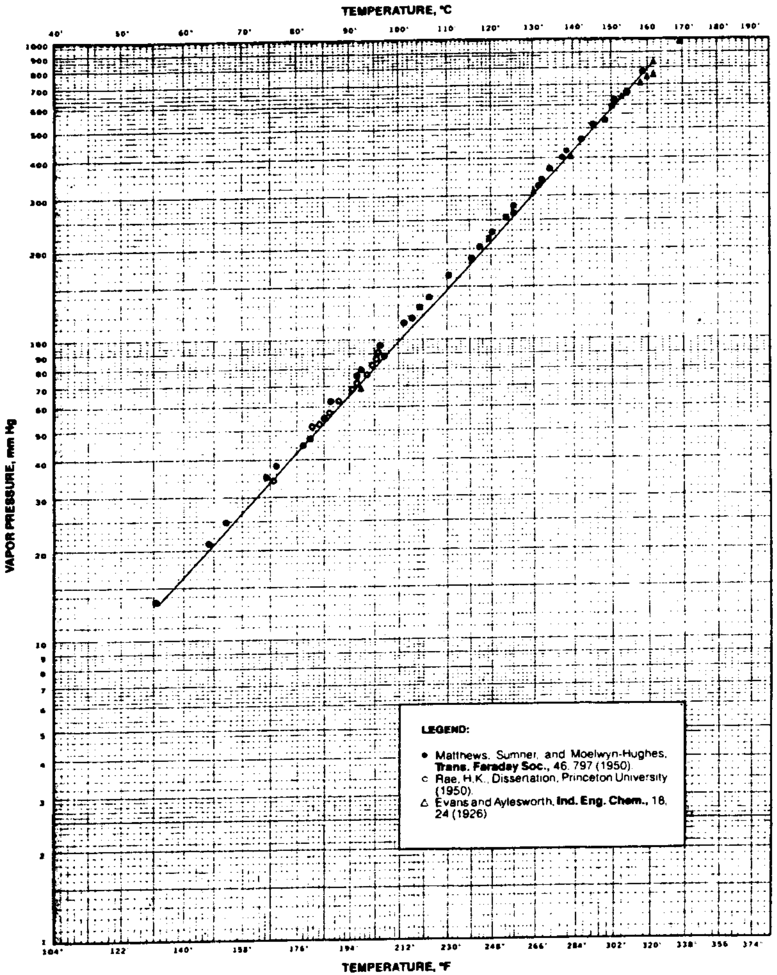
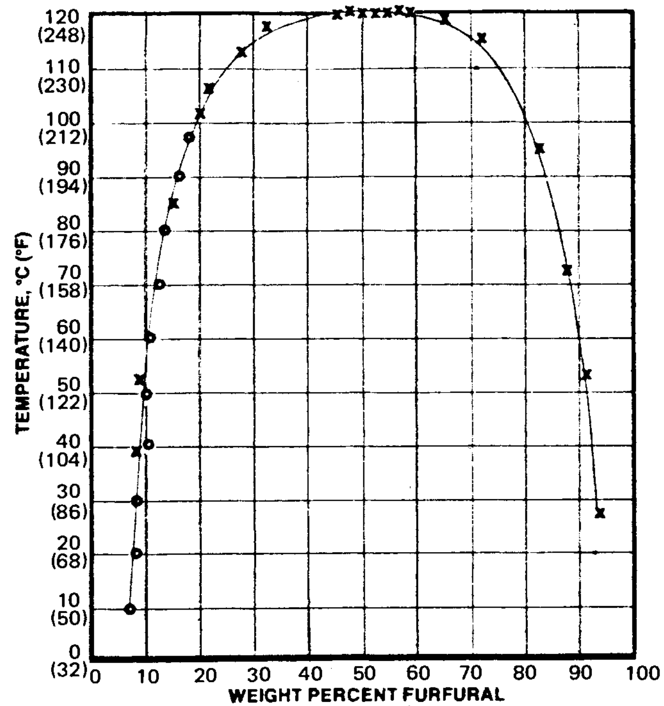


Table 9.8: Solution Temperature of Furfural-Water System *(46)*

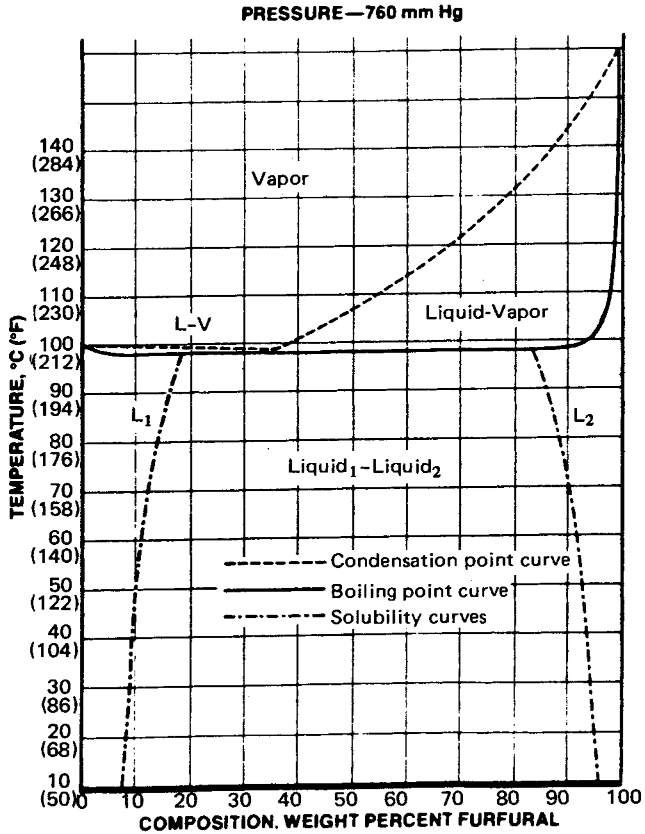


LEGEND:

O Mains, G. H., **Chem. & Met. Eng.**, 26, 779 (1922)

X Evans, W. V. and Aylesworth, M. B., **Ind. Eng. Chem.** 18, 24 (1926)

Table 9.9: Temperature-Composition Diagram of Furfural-Water System* *(46)*



*Mains, G.H., **Chem. & Met. Eng.**, 26, 779(1922)

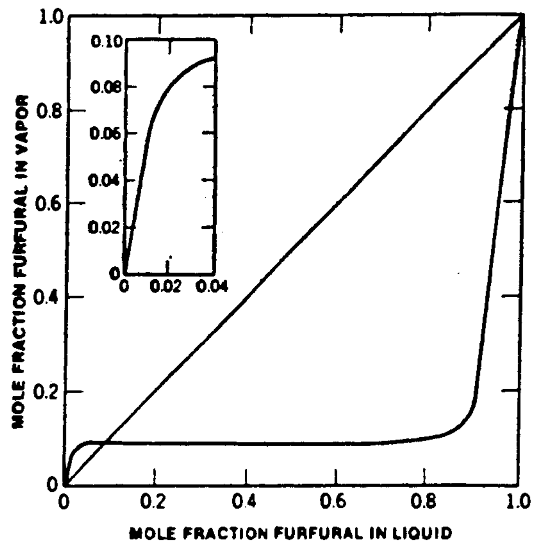
Table 9.10: Vapor-Liquid Equilibrium in the Furfural-Water System[1] *(46)*

(PRESSURE = 760 mm Hg)

% FURFURAL BY WEIGHT		BOILING POINT	
COMPOSITION OF LIQUID	COMPOSITION OF VAPOR	°C	°F
0.2	1.5	99.90	211.8
0.4	3.0	99.82	211.68
0.6	4.4	99.74	211.53
0.8	5.8	99.67	211.41
1.0	7.0	99.60	211.28
1.5	10.0	99.42	210.96
2.0	12.7	99.25	210.65
2.5	15.0	99.11	210.40
3.0	17.1	98.99	210.18
3.5	19.0	98.87	209.97
4.0	20.7	98.76	209.77
4.5	22.2	98.66	209.59
5.0	23.6	98.58	209.44
5.5	24.8	98.50	209.30
6.0	25.8	98.43	209.17
6.5	26.8	98.37	209.07
7.0	27.7	98.31	208.96
7.5	28.5	98.26	208.87
8.0	29.2	98.21	208.78
8.3[2]	29.6	98.19	208.74
8.5	29.9	98.17	208.71
9.0	30.5	98.13	208.63
10.0	31.7	98.07	208.53
11.0	32.6	98.02	208.44
12.0	33.3	97.98	208.36
13.0	33.9	97.95	208.31
14.0	34.4	97.93	208.27
15.0	34.7	97.92	208.26
16.0	34.8	97.91	208.24
17.0	34.9	97.91	208.24
18.0	35.0	97.90	208.22
18.4[3]	35.0	97.90	208.22
18.4-84.1[4]	35.0	97.90	208.22

[1] Mains, G.H., Chem. & Met. Eng., 26, 779 (1922).
[2] Saturated solution of furfural in water at 20° C (68° F).
[3] Saturated solution of furfural in water at the boiling point.
[4] Range over which both furfural and water layers are present.

Table 9.11: Vapor-Liquid Composition of Furfural-Water System *(46)*



OTHER ALDEHYDES

Table 9.12: Vapor Pressures of Various Aldehydes *(19)*

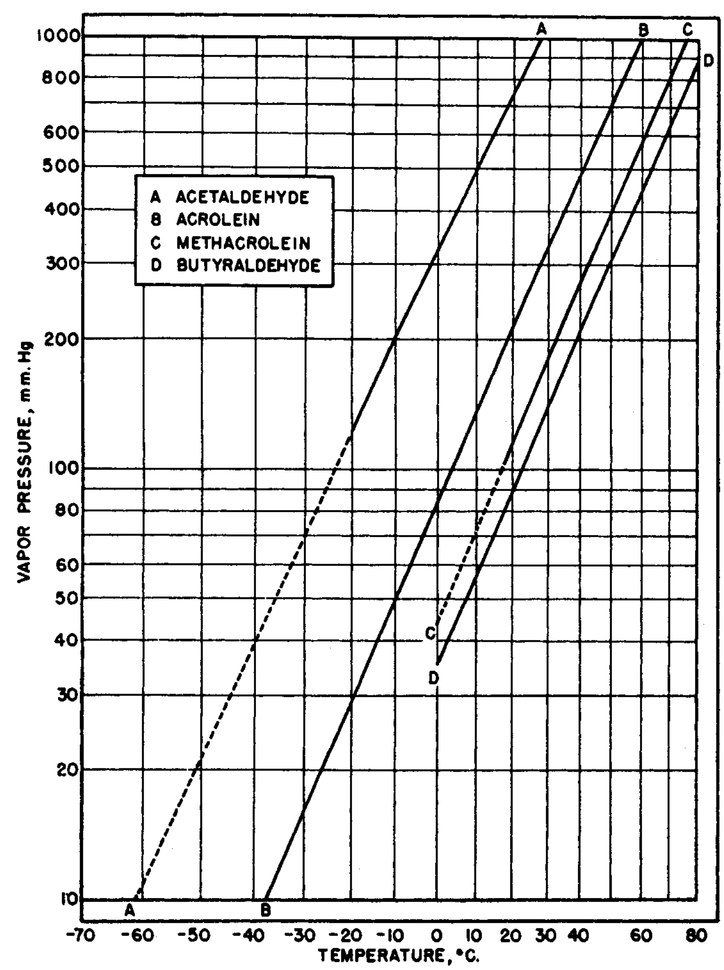


Table 9.13: Physical Properties of Various Aldehydes *(19)*

Product	Formula	Formula Molecular Weight	Purity of Tested Sample, % by wt.	Apparent Specific Gravity, 20/20°C.	Boiling Point, °C., 760 mm.	Vapor Pressure, mm. Hg at 20°C.	Freezing Point, °C.	Solubility, % by weight at 20° C. In Water	Solubility, % by weight at 20° C. Water In	Pounds Per Gal. at 20°C.	Flash Point, °F. (a)
Formaldehyde, 37% (uninhibited)	HCHO	30.03	(c)	0.816(g)	—19.1	3284	—117	Complete		9.24(h)	None
Paraldehyde	$[CH_3CHO]_3$	132.16	(c)	0.9961	124	26	12.6	10.5	1.1	8.27	96
Propionaldehyde	C_2H_5CHO	58.08	(c)	0.7982	48.0	258	—80	22	35	6.72	<0
Butyraldehyde	C_3H_7CHO	72.11	(c)	0.8028	74.8	88.5	—96.4	$7.1_{25°C.}$	$3.0_{25°C.}$	6.69	15
Isobutyraldehyde	$CH_3CH(CH_3)CHO$	72.11	(c)	0.7905	64.1	138	....	6.5	2.9	6.58	13
Valeraldehyde	C_4H_9CHO	86.13	(c)	0.8109	103.0	26	—91	1.35	1.35	6.75	54
2-Methylpentaldehyde	$C_3H_7CH(CH_3)CHO$	100.16	(c)	0.8102	118	14	—100(d)	0.42	0.83	6.74	72
2,3-Dimethyl Pentaldehyde	$C_2H_5CH(CH_3)CH(CH_3)CHO$	114.19	(c)	0.8293	140.5	5	—110	0.21	0.60	6.91	94
Acrolein	CH_2:CHCHO	56.06	99	0.8427	53	220	—87.0	20.6	6.8	7.02(i)	<0(i)
Tetrahydrobenzaldehyde	CH_2CH:$CHCH_2CH_2CHCHO$ (ring)	110.16	99.8	0.9721	165	2	—100(d)	0.5	1.0	8.08	135
UCAR Glyoxal 40 (aq. sol.)	OHCCHO	58.04	(e)	1.2798	....	....	—15	Complete		10.65	None
UCAR Glyoxal LV	....	....	(e)	1.2851	....	....	—15	Complete		10.69	None
Glutaraldehyde, 25% aq. sol.	$OHCC_3H_6CHO$	100.12	(e)	1.062	....	17	—7.0	Complete		8.83	None
Glutaraldehyde, 50% aq. sol.	$OHCC_3H_6CHO$	100.12	(e)	1.124	....	17	—14.0	Complete		9.38	None

(a) All flash points were determined by either ASTM method D 1310 using Tag open cup or ASTM method D 92 using Cleveland open cup.

(c) 99+ mol per cent material.

(d) Sets to glass below this temperature.

(e) Typical commercial material.

(f) Made from anhydrous isopropanol diluted with demineralized water.

(g) True density at—19°C.

(h) 37% Solution.

(i) Inhibited material.

Ethers

Table 10.1: Dimethyl Ether *(34)*

Methyl Ether

$CH_3—O—CH_3$

Physical Properities

Property	Value
Molecular weight (calc.)	46.07
Boiling point at 760 mm	−24.9°C
Vapor pressure at 20°C	5.24 atm
Freezing point	−141.5°C
Density at 20°C	0.661 g/ml
Vapor density (air = 1.0)	1.59
Critical pressure	52.5 atm
temperature	128.8°C
density	0.2714 g/ml
Heat of combustion, gas	347.6 kcal/mole
Heat of formation, gas	−44.3 kcal/mole
Heat of melting	25.621 cal/g
Heat of vaporization at −24.8°C	111.64 cal/g
Free energy of formation, 25°C	−27.3 kcal/mole
Entropy at 25°C	63.72 cal/°C—mole
Specific heat at −27.68°C	0.5351 cal/g
Surface tension, liquid-vapor interface, at −40°C	21 dynes/cm
−20	18
−10	16

Property	Value
Viscosity of gas at 0°C, $\eta \times 10^7$	825
20	855
Dielectric constant at 25°C	5.02 e.s.u.
Flash point, Tag closed cup	−42°F
Autoignition temperature	662°F
Explosive limits, % by vol. in air	3.45-26.7%
Solubility* in water at 24°C	35.3% by wt.
Solubility* of water in methyl ether at 24°C	7.0% by wt.
Solubility in gasoline (unleaded) at −40°C	64% by wt.
0	19
25	7
Solubility at 25°C in: carbon tetrachloride at 782 mm	16.33 mole %
acetone 762	11.83
benzene 761	15.29
chlorobenzene 795	18.55
methyl acetate 704	11.17

* At about 5 atm.

SOME PHYSICAL AND THERMODYNAMIC PROPERTIES OF DIMETHYL ETHER AT VARIOUS TEMPERATURES

Temperature °C	Vapor pressure atm.	Density		Dielectric constant	Heat of vaporization kcal/kg	Enthalpy		Entropy	
		liquid g/ml	vapor g/ml			liquid kcal/kg	vapor kcal/kg	liquid cal/(g)(°K)	vapor cal/(g)(°K)
−40	0.392	—	—	—	116.13	77.58	193.71	0.9109	1.4090
−30	0.741	—	—	—	113.17	83.08	196.25	0.9342	1.3996
−20	1.35	0.7174	0.0027	—	110.12	88.64	198.76	0.9568	1.3918
−10	1.97	.7040	.0039	—	106.95	94.23	201.23	0.9787	1.3851
0	2.80	.6905	.0055	—	103.64	100.00	203.64	1.0000	1.3794
10	3.86	.6759	.0076	—	100.17	105.79	205.96	1.0206	1.3744
20	5.24	.6610	.0104	5.15	96.44	111.75	208.19	1.0410	1.3700
30	7.00	.6455	.0142	4.90	92.64	117.60	210.24	1.0604	1.3660
40	9.06	.6292	.0188	4.67	88.48	123.63	212.11	1.0795	1.3620
50	11.6	.6116	.0241	4.41	—	—	—	—	—
60	14.7	.5932	.0306	4.18	—	—	—	—	—
70	18.4	.5735	.0385	3.93	—	—	—	—	—
80	22.7	.5517	.0484	3.70	—	—	—	—	—
90	27.4	.5257	.0623	3.48	—	—	—	—	—
100	33.0	.4950	.0810	3.25	—	—	—	—	—
110	39.5	.4575	.1060	3.00	—	—	—	—	—
120	46.6	.4040	.1465	—	—	—	—	—	—

(continued)

Table 10.1: (continued)

Some Properties of $(CH_3)_2O{\cdot}BF_3$

Molecular weight (calc.)	113.89
Melting point	−12°C
Boiling point	128°C
Density at 20°C	1.241 g/ml
Vapor pressure at 30°C	6.1 torr
at 70°C	52.7 torr
Surface tension at 20.5°C	33.03 dynes/cm
Dissociation constant	$\log K = (-2983)/T + 7.228$

Binary Azeotropes Containing Dimethyl Ether

Component A	Azeotrope Boiling point, °C	Azeotrope Component A, % by wt
Boron trifluoride	127	60
Hydrogen chloride	−2	38
Ammonia at 1 atm	−37	42.5
at 11 atm	25	56
Sulfur dioxide at 1 atm	0	65
at 56.1 atm	6.6	60
at 77.1 atm	12.1	60
at 108.7 atm	26.7	60
Dichlorodifluoromethane at 3 atm	0	90

Solubility of Methyl Ether at Various Pressures

Temperature = 25°C

Carbon tetrachloride		Acetone		Benzene		Chlorobenzene		Methyl acetate	
p,mm	Methyl ether, Mole %	p,mm	Methyl ether, Mole %	p,mm	Methyl ether, Mole %	p,mm	Methyl ether, Mole %	p,mm	Methyl ether, Mole %
112.4	0.000	229.2	0.0	93.7	0.0	11.6	0.0	213.4	0.0
237.6	3.0	311.7	1.79	196.9	2.30	120.4	6.21	293.2	1.75
360.1	5.96	403.1	3.78	372.6	6.32	310.5	7.20	440.6	5.08
464.8	8.52	548.2	7.01	503.0	9.32	423.3	9.74	576.0	8.17
612.8	12.17	650.8	9.33	634.8	12.29	550.8	12.78	704.4	11.17
782.4	16.33	762.3	11.83	761.4	15.29	795.3	18.55	812.3	13.65
932.7	19.93	939.1	15.77	913.0	18.84	957.9	22.14	923.5	16.27
1072.9	23.30	1075.0	18.93	1006.7	21.00	1072.1	24.71	1039.7	19.50

Table 10.2: Chlorodimethyl Ether *(2)*

$CH_3{-}O{-}CH_2Cl$

Chlorodimethyl ether is a colorless liquid which decomposes in water and in hot ethyl alcohol. It is soluble in acetone, carbon disulfide and concentrated hydrochloric acid.

Physical Properties

Boiling Point (760 mm. Hg), °C.	59
Dipole Moment	
In Carbon Tetrachloride D	1.88
In Benzene D	1.82 - 1.85
Melting Point, °C.	-103.5
Molecular Weight	80.52
Purity	90% min.
Refractive Index n_D^{20}	1.39737
Specific Gravity D_4^{20}	1.0703

Table 10.3: Chlorometyl Ethyl Ether *(2)*

$ClCH_2—O—CH_2—CH_3$

This ether is a colorless liquid which is an irritant to the mucous membranes. It is used as a raw material in organic syntheses.

Physical Properties

Assay (chlorine)	App. 98%
Boiling Range, 760 mm. Hg, °C.	79 - 83
Density D_4^{20}	1.03 - 1.05
Refractive Index n_D^{20}	1.40 - 1.41

Table 10.4: Ethyl Ether *(1)(19)(23)(49)*

Ether
Ethyl oxide
Sulfuric ether

$C_2H_5—O—C_2H_5$

Typical Properties and Specifications

Apparent ignition temperature in air	190°C.
Boiling point at 760 mm.	34.5°C.
Coefficient of expansion	0.00164 per 1°C.
Constant-boiling mixtures (% by wt.)	
Ethyl ether 99% Carbon disulfide 1.0%	B.P. at 760 mm. 34.5°C.
Ethyl ether 44.5% Methyl formate 55.5%	B.P. at 760 mm. 28.2°C.
Ethyl ether 98.9% Water 1.1%	B.P. at 760 mm. 34.1°C.
Electrical conductivity at 25°C.	4×10^{-13} recip. ohm
Explosive limits	2.34 - 6.15%
Flash point	-40°F.
Freezing point	-116.2°C.
Heat of combustion	651 Cal./mol
Heat of vaporization	83.96 cal./g at B.P.
Refractive index at 17°C.	1.3542
Specific gravity at 20/20°C.	0.7146
Specific heat at 30°C.	0.5476 cal./g.
Surface tension at 20°C.	17.0 dynes/sq. cm.
Solubility in water at 20°C.	6.9% by wt.
Solubility of water in solvent at 20°C.	1.3% by wt.
Viscosity at 20°C.	0.00233 poise
Vapor pressure at 20°C.	442.0 mm. Hg
Weight per gallon at 20°C.	5.95 lbs.
Weight per gallon at 17°C.	5.3542 lbs.
Acidity (as acetic)	0.002% by wt., max.

Table 10.5: Flammability of Ethyl Ether-Oxygen-Helium Mixture *(1)*

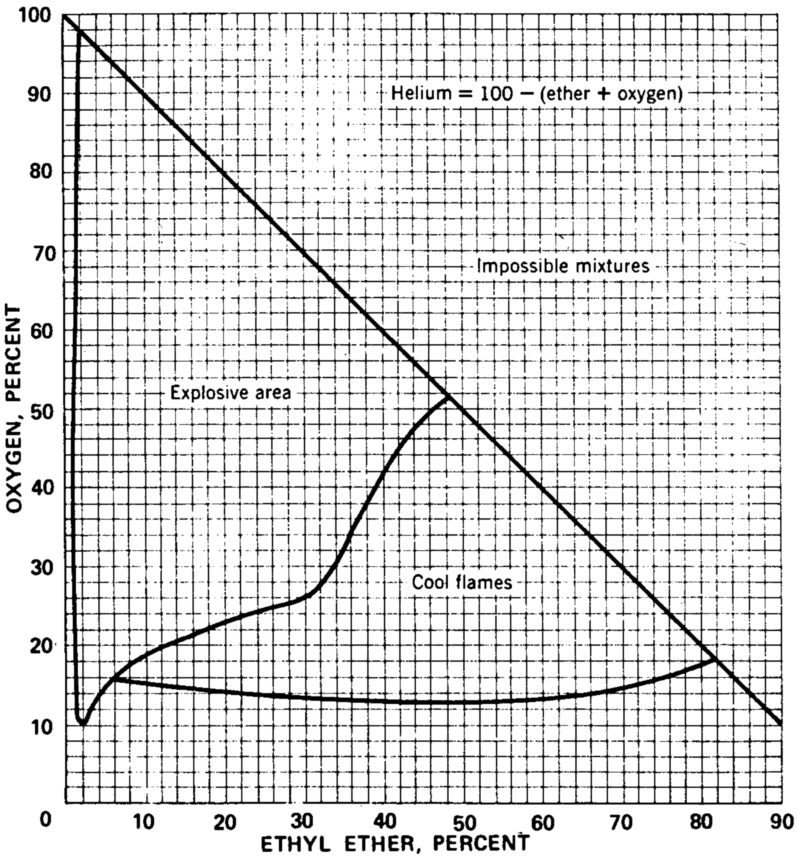


Table 10.6: Dichloroethyl Ether *(2)*

2,2′-Dichlorethyl Ether
β,β′-Dichlorodiethyl Ether

Cl—CH2—CH2—O—CH2—CH2—Cl

Acidity (as hydrochloric)	0.005% by wt. max.	Heat of vaporization at 178°C.	64.1 cal./g.
Apparent ignition temperature in air	396°C.	Refractive index at 20°C.	1.457
Boiling point at 760 mm.	178.5°C.	Specific gravity at 20/20°C.	1.2220
Boiling range at 760 mm.	170-180°C.	Specific heat (at 20-30°C.)	0.369 cal.
Coefficient of expansion at 20°C.	0.00097 (per °C.)	Surface tension at 25°C.	41.8 dynes/sq. cm.
Coefficient of expansion at 55°C.	0.00100 (per °C.)	Solubility in water at 20°C.	1.1% by wt.
Constant boiling mixture (% by wt.)		Solubility of water in dichlorethyl ether at 20°C.	0.28% by wt.
Dichlorethyl ether	34.4	Viscosity at 25°C.	2.0653 centipoises
Water	65.6	Vapor pressure at 20°C.	0.7 mm. Hg
B.P. at 760 mm.	97.7°C.	Water content	0.10% by wt. max.
Flash Point (ASTM, open cup)	79°C.	Weight per gal. at 20°C.	10.17 lbs.
Flash Point (ASTM, closed cup)	55°C.		

ISOPROPYL ETHER

Table 10.7: Properties of Pure Isopropyl Ether *(14)*

Molecular Formula	$C_6H_{14}O$
Molecular Weight	102.172
Boiling Point, °C	68.5
Boiling Point Change, °C/mm at 760 mm	0.042
Freezing Point, °C	-85.5
Density at 20°C, g/ml (in vacuo)	0.7235
at 60°F, lb/US gal (in air)	6.07
Specific Gravity, 20/20°C (in air)	0.7244
Coefficient of Expansion (1) at 20°C, per °C	0.00143
Refractive Index, n0/D	1.3784
n20/D	1.36820
n30/D	1.36301
Critical Temperature, °C	288
Critical Pressure, atm	27.5
Critical Volume, cc/g	3.80
Heat of Vaporization (2,3), 760mm, cal/g	68.16
Heat of Fusion at Melting Point (4), cal/g	25.79
Heat of Formation (5) (vapor at 25°C) k-cal/mole	-77
Free Energy of Formation (4) (vapor at 25°C) k-cal/mole	-31
Specific Heat (Liquid), cal/g°C (at 20°C)	0.506
Thermal Conductivity (Vapor at 100°C) cal/(sec) (cm²) (°C/cm)	0.0000483
Viscosity, cps at -20°C	0.545
0°C	0.419
20°C	0.333
50°C	0.255
Surface Tension (6), 25°C, dynes/cm	17.28
Dielectric Constant (7), 85.8 kHz, 25°C	4.449

Other Properties of Commercial IPE

Autoignition Temp., °F	830
Flash Point (8), Tag Open Cup, °F (approx.)	+15
Tag Closed Cup, °F (approx.)	-18
Flammable Limits of Vapor with Air	
% vol. of Compound, Upper	21
Lower	1.4
Relative Evaporation Rate at 25°C and 0% R.H.; Shell Thin Film Evaporometer (n-BuOAc = 1.0)	8.04

References

1. Calculated from density measurements as $\frac{.7242 - .7139}{.7190 \times 10}$
2. Calculated via Clapeyron Equation Z = 0.95.
3. Fife & Reid, Ind. Eng. Chem. *22*, 513 (1930)
4. Parks, et. al., J. Am. Chem. Soc. *55*, 2735 (1933)
5. Kharasch, M. S., J. Research, Nat'l Bur. Stds. *2*, 359 (1929)
6. Vogel, A. I., J. Chem. Soc. Part I, 616 (1948)
7. Kirk-Othmer, "Ency. of Chem. Tech." 5, 870 (1950)
8. Petroleum Engineer, June 1945, 219.

Table 10.8: Vapor Pressure of Isopropyl Ether[1] *(14)*

t°C	mm Hg	t°C	mm Hg	t°C	mm Hg
-20	13.4	15	94.4	50	406.6
-15	18.4	20	119.4	55	485.8
-10	24.9	25	149.5	60	576.7
-5	33.3	30	185.6	65	680.3
0	44.0	35	228.4	70	797.8
5	57.3	40	278.9	75	930.1
10	74.0	45	338.0	80	1078.7

[1]Log VP mm Hg = 23.16817 - 2382.7/T - 5.2545Log T
T = 273.15 + t°C

Table 10.9: Isopropyl Ether-Water Solubility *(14)*

	%wt			%wt	
t°C	IPE in H_2O	H_2O in IPE	t°C	IPE in H_2O	H_2O in IPE
-10	—	0.41	50	0.73	0.82
0	—	0.43	60	0.73	0.93
10	1.43	0.47	70	0.76	1.06
20	1.07	0.53	80	0.83	1.20
30	0.88	0.62	90	0.92	1.34
40	0.78	0.72	100	1.04	1.49

Table 10.10: Mutual Solubility for the System: Isopropyl Ether-Isopropyl Alcohol-Water at 25°C, % wt *(14)*

IPE	H_2O	IPA	Sp. Gr.25/4° C
99.5	0.5		0.7210
93.4	1.1	5.5	0.7274
89.0	1.5	9.5	0.7326
84.4	2.2	13.4	0.7380
79.9	3.2	16.9	0.7427
74.4	4.6	21.0	0.7490
72.8	4.7	22.5	0.7509
70.3	5.2	24.5	0.7547
68.7	5.8	25.5	0.7564
65.3	6.7	28.0	0.7605
64.0	7.1	28.9	0.7620
61.5	7.8	30.7	0.7641
58.3	8.9	32.8	0.7698
56.4	9.6	34.0	0.7726
50.8	11.6	37.6	0.7812
47.6	13.0	39.4	0.7864
42.6	15.5	41.9	0.7958
38.6	17.8	43.6	0.8029
35.7	19.7	44.6	0.8091
31.5	23.0	45.5	0.8189
28.3	26.0	45.7	0.8275
24.8	29.7	45.5	0.8379
22.6	32.4	45.0	0.8450
18.9	37.6	43.5	0.8590
16.3	41.9	41.8	0.8707
14.5	45.0	40.5	0.8789
12.6	48.4	39.0	0.8884
12.2	49.0	38.8	0.8897
10.6	52.1	37.3	0.8982
8.6	55.6	35.8	0.9084
6.6	60.2	33.2	0.9200
5.9	61.8	32.3	0.9245
5.2	63.6	31.2	0.9293
4.7	65.0	30.3	0.9334
3.4	69.6	27.0	0.9437
2.2	74.8	23.0	0.9568
1.6	78.3	20.1	0.9634
1.3	83.3	15.4	0.9716
1.2	89.4	9.4	0.9796
1.0	93.8	5.2	0.9864
0.9	99.1		0.9928

Reference: Frere, F. J., Ind. Eng. Chem. *41*, 2365 (1949)

Table 10.11: Conjugate Solutions in the System: Isopropyl Ether-Isopropyl Alcohol-Water at 25°C, % wt (14)

Upper Layer			Tie	Lower Layer		
IPE	H_2O	IPA	Line[1]	IPE	H_2O	IPA
96.4	0.8	2.8	1	1.0	92.1	6.9
93.0	1.2	5.8	2	1.2	89.0	9.8
90.1	1.5	8.4	3	1.2	86.9	11.9
86.1	2.0	11.9	4	1.2	85.4	13.4
82.8	2.7	14.5	5	1.2	83.8	15.0
76.3	4.0	19.7	6	1.3	82.4	16.3
72.1	5.0	22.9	7	1.4	81.6	17.0
64.2	7.0	28.8	8	1.4	80.3	18.3
54.2	10.2	35.6	9	1.7	77.8	20.5
45.4	14.0	40.6	10	2.3	74.1	23.6
36.9	18.7	44.4	11	2.9	71.2	25.9
31.5	23.0	45.5	12	3.7	68.3	28.0
25.3	29.0	45.7	13	4.7	64.6	30.7
Estimated plait point[2]				9.8	53.3	36.9

[1] See Table 10.12
[2] Point at which two layers converge into one phase.

Reference: Frere, F.J., *Ind. Eng. Chem.* 41, 2365 (1949).

Table 10.12: Miscibility of Isopropyl Ether-Isopropyl Alcohol-Water at 25°C (14)

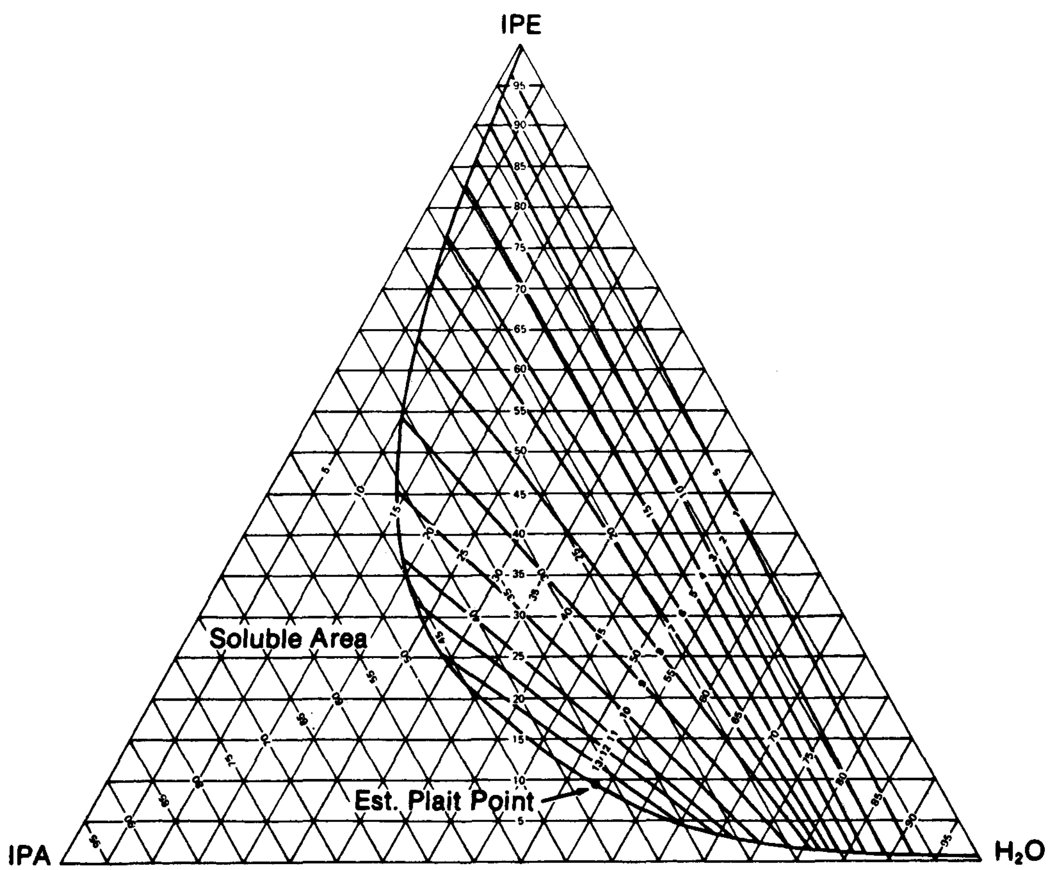


Table 10.13: Azeotropic Information-Isopropyl Ether *(14)*

Ternary Azeotrope: IPA — IPE — Water
(Boiling Point 61.7°C)

Component	Azeotrope	Upper Layer	Lower Layer
IPA (Isopropyl Alc.)	6.0	5.8	10.0
IPE	89.0	93.1	1.0
Water	5.0	1.1	89.0
%w	100	95.6	4.4

Other Azeotropic Information

Binary Azeotropes

B.P. °C	Other Components	%wt Other Component
61.	Boron Triflouride	40
62.2	Water	4.5
70.5	Chloroform	36
<67.5	Propronitrile	> 4
74.0	2, 2-Dichloropropane	60
54.2	Acetone	61
66.2	Isopropyl Alcohol	16.3
66.0	1-Propanethiol	65
>69.0	1-chloro-2-methylpropane	—
<68.0	Methylocyclopentane	< 20
67.5	Hexane	47

Ternary Azeotropes

B.P. °C	Components and %wt
66	H_2O, 7.0%; Ethyl alcohol 14.7%; IPE 78.3%
Min B.P.	H_2O — %; Acetone — %; IPE — %
Nonazeotrope	H_2O — Sec. Butyl alcohol — IPE

IPE does not form azeotropes with

Trichloroethylene
1,1-Dichloroethane
1,2-Dichloroethane
2-Chloroethanol
Iodoethane
2-Bromopropane
Thiophene
2-Bromo-2-methylpropane
1-Chlorobutane
Ethyl sulfide
Diethoxymethane
Benzene
Hexyl Alcohol

Table 10.14: Vapor Pressure of Isopropyl Ether at Various Temperatures *(8)*

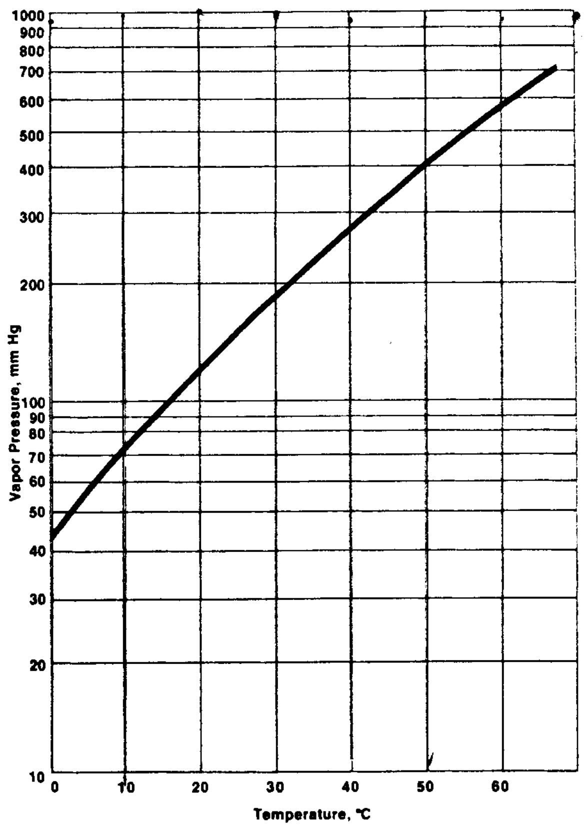


Table 10.15: Specific Gravity of Isopropyl Ether vs Temperature *(8)*

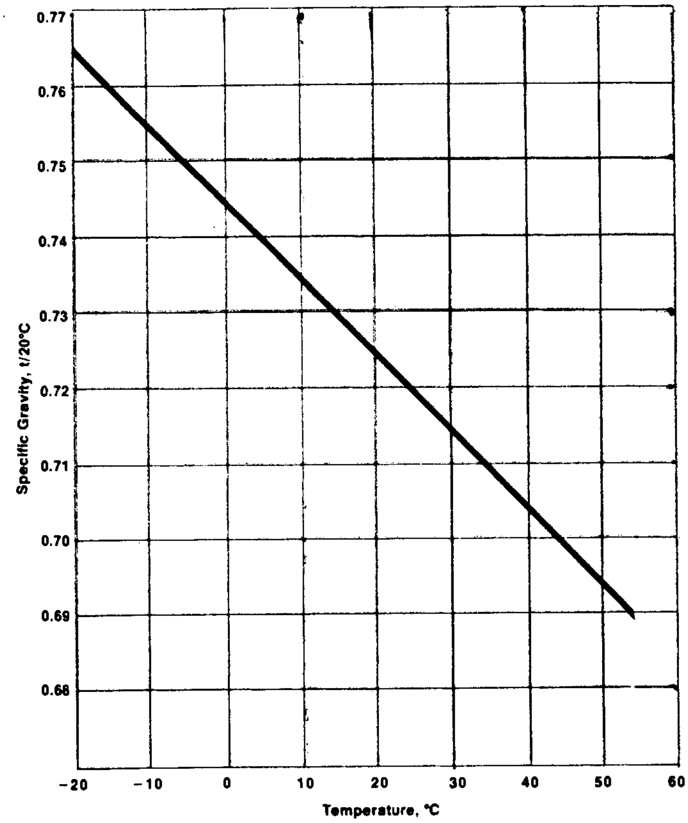


Table 10.16: Mutual Solubility and Specific Gravity of Isopropyl Ether, Water and Isopropyl Alcohol at 25°C *(2)*

Isopropyl Ether	Water	Isopropyl Alcohol	SG $d_4^{25°C}$
99.5	0.5	- -	0.7210
93.4	1.1	5.5	0.7274
89.0	1.5	9.5	0.7326
84.4	2.2	13.4	0.7380
79.9	3.2	16.9	0.7427
74.4	4.6	21.0	0.7490
72.8	4.7	22.5	0.7509
70.3	5.2	24.5	0.7547
68.7	5.8	25.5	0.7564
65.3	6.7	28.0	0.7605
64.0	7.1	28.9	0.7620
61.5	7.8	30.7	0.7641
58.3	8.9	32.8	0.7698

(continued)

Table 10.16: (continued)

Isopropyl Ether	Water	Isopropyl Alcohol	SG $d_{4}^{25°C.}$
56.4	9.6	34.0	0.7726
50.8	11.6	37.6	0.7812
47.6	13.0	39.4	0.7864
42.6	15.5	41.9	0.7958
38.6	17.8	43.6	0.8029
35.7	19.7	44.6	0.8091
31.5	23.0	45.5	0.8189
28.3	26.0	45.7	0.8275
24.8	29.7	45.5	0.8379
22.6	32.4	45.0	0.8450
18.9	37.6	43.5	0.8590
16.3	41.9	41.8	0.8707
14.5	45.0	40.5	0.8789
12.6	48.4	39.0	0.8884
12.2	49.0	38.8	0.8897
10.6	52.1	37.3	0.8982
8.6	55.6	35.8	0.9084
6.6	60.2	33.2	0.9200
5.9	61.8	32.3	0.9245
5.2	63.6	31.2	0.9293
4.7	65.0	30.3	0.9334
3.4	69.6	27.0	0.9437
2.2	74.8	23.0	0.9568
1.6	78.3	20.1	0.9634
1.3	83.3	15.4	0.9716
1.2	89.4	9.4	0.9796
1.0	93.8	5.2	0.9864
0.9	99.1	- -	0.9928

Table 10.17: n-Butyl Ether *(2)*

$$C_4H_9OC_4H_9$$

n-Butyl ether is a colorless, stable liquid, soluble in water. Having two butyl groups, this ether is an excellent solvent for many natural and synthetic resins, gums, oils, fats, organic acids, esters, and alkaloids. Beeswax and carnauba wax have limited solubility in butyl ether at room temperature, but become quite soluble at higher temperatures. n-Butyl ether will not dissolve cellulose acetate, benzyl cellulose, or cellulose nitrate, but when it is mixed with ethyl or butyl alcohol it becomes a solvent for ethylcellulose. Butyl ether is used as a reaction medium in organic synthesis and in the extraction and purification of essential oils, organic acids, waxes and resins.

Typical Properties and Specifications

Boiling point at 760 mm	142.4°C
50	63
10	28
Color	Water-white
Flash point	30.6°C
Heat of vaporization	68.8 cal./g
Freezing point	Approx. −96°C
Specific gravity at 20/20°C	0.769–0.771
Refractive index at 20°C	1.3992
Surface tension at 20°C	22.9 dynes per sq cm
Solubility in water at 20°C	0.03%
Solubility of water in solvent at 20°C	0.19%
Vapor pressure at 20°C	4.8 mm Hg
Weight per gallon at 20°C	6.4 lbs
Acidity (as butyric)	0.05% by wt., max.
Distillation range	137–143°C
Water content	0.10% by wt., max.

Table 10.18: Diamyl Ether *(2)*

$C_5H_{11}OC_5H_{11}$

Commercial diamyl ether consists principally of di-n-amyl ether and di-isoamyl ether, with small percentages of isomeric amyl ethers and diamylene. It is a colorless to light yellow liquid which is quite stable. It is insoluble in water but soluble in methanol, ethyl ether, ethyl acetate, acetone, aliphatic and aromatic hydrocarbons, fixed oils, oleic and hot stearic acids, hot paraffin and carnauba waxes, the latter two solidifying when cooled. Unlike the lower aliphatic ethers, it will not dissolve nitrocellulose when admixed with ethanol. However, a mixture of diamyl ether and 20% ethanol will dissolve ethylcellulose.

Typical Properties and Specifications

Dielectric constant	3.14
Flash point (open cup)	146°F
Heat of vaporization	65.9 cal./g (calc'd)
Specific gravity at 20/20°C	0.78–0.80
Specific heat	0.513 cal/g
Refractive index at 20°C	1.4198
Surface tension at 20°C	24.8 dynes/sq cm
Freezing point	Below −75°C
Vapor pressure at 20°C	0.67 mm
Water azeotrope at 96–98°C	41% amyl ether (approx.)
Weight per gallon at 20°C	6.61 lbs
Acidity (mg. KOH per g)	0.4, max.
Distillation	
Initial boiling point	Not below 170°C
Not less than 95%	Below 200
Final boiling point	Not above 210
Water content	0.2% by wt., max.

Table 10.19: n-Hexyl Ether *(2)*

$C_6H_{13}OC_6H_{13}$

n-Hexyl ether is a colorless, stable liquid with a mild odor. It is less volatile than the lower members of the aliphatic ether group and its solubility in water is very slight. It is miscible with most organic solvents and can replace butyl ether for many similar applications. It is used as a solvent medium in chemical reactions and is a foam breaker for certain processes.

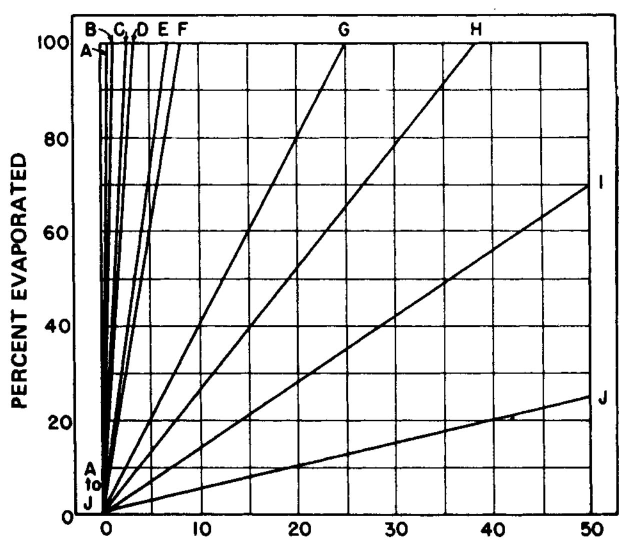
Boiling point at 760 mm.	226.2°C.
Boiling point at 50 mm.	136°C.
Boiling point at 10 mm.	100°C.
Flash Point	170°F.
Specific gravity at 20/20°C.	0.7942
Solubility in water at 20°C.	0.01% by wt.
Solubility of water in solvent at 20°C.	0.12% by wt.
Vapor pressure at 20°C.	0.07 mm. Hg
Weight per gallon at 20°C.	6.61 lbs.
Acidity (as acetic)	0.01% by wt., max.
Distillation range at 760 mm.	205 - 235°C.
Color (A.P.H.A.)	15 max.
Water content	0.10% by wt.

Table 10.20: Solubility Data for Various Ethers *(19)*

Substance	Ethyl	Isopropyl	Butyl	Dioxane	Dichlor-ethyl	Dichlor-isopropyl
	Types of Ethers as Solvents					
"Bakelite" vinyl resin AYAF	I	I	SW-G	S	S	S
"Bakelite" vinyl resin VYHH	I	I	I	S	S	SW
Cellulose nitrate (dry)	SA	SA	I	SA	SA	I
Cellulose acetate	I	I	I	S	SA	I
Buna S	–	–	–	–	–	–
Neoprene GN	–	–	–	–	–	–
Carnauba wax	–	SS	–	SW	SW	–
Paraffin wax	–	S	–	SW	S	–
Beeswax	–	SW	–	SW	SW	S
Rosin	S	S	–	S	I	S
Dewaxed dammar	S	SS	S	S	I	S
Zein	–	–	–	–	–	–
Soluble starch	–	–	–	–	–	–
Gelatin	–	–	–	–	–	–
Hydrocarbons	S	S	S	S	S	S
Linseed oil (raw)	S	S	S	S	S	S
Shellac	I	I	SSW	S	I	SSW
Kauri gum	I	I	S	S	I	SW
Ester gum	S	S	S	S	S	S
Unvulcanized rubber	S	S	S-G	SS	I	SS-G

S: soluble SS: slightly soluble I: insoluble
G: tendency to gel SA: soluble with alcohol W: when warm

Table 10.21: Comparative Evaporation Rates of Various Ethers *(19)*



(A) Ethyl ether
(B) Acetone
(C) Isopropyl ether
(D) Ethyl acetate
(E) Dioxane
(F) Butyl acetate (90%)
(G) "Cellosolve" solvent
(H) "Cellosolve" acetate
(I) Dichlorethyl ether
(J) Diethyl "Carbitol"

Table 10.22: Specific Gravities of Various Ethers *(19)*

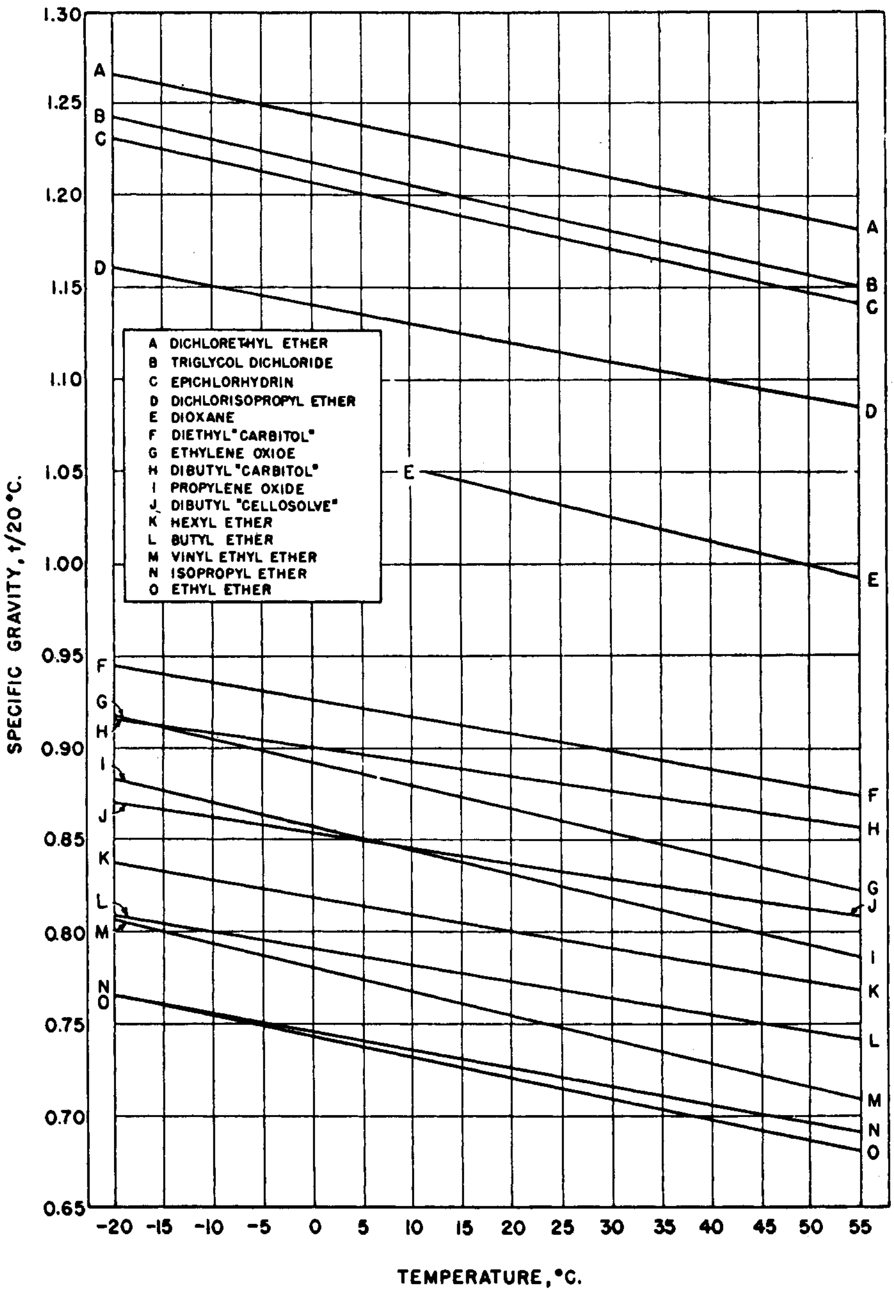
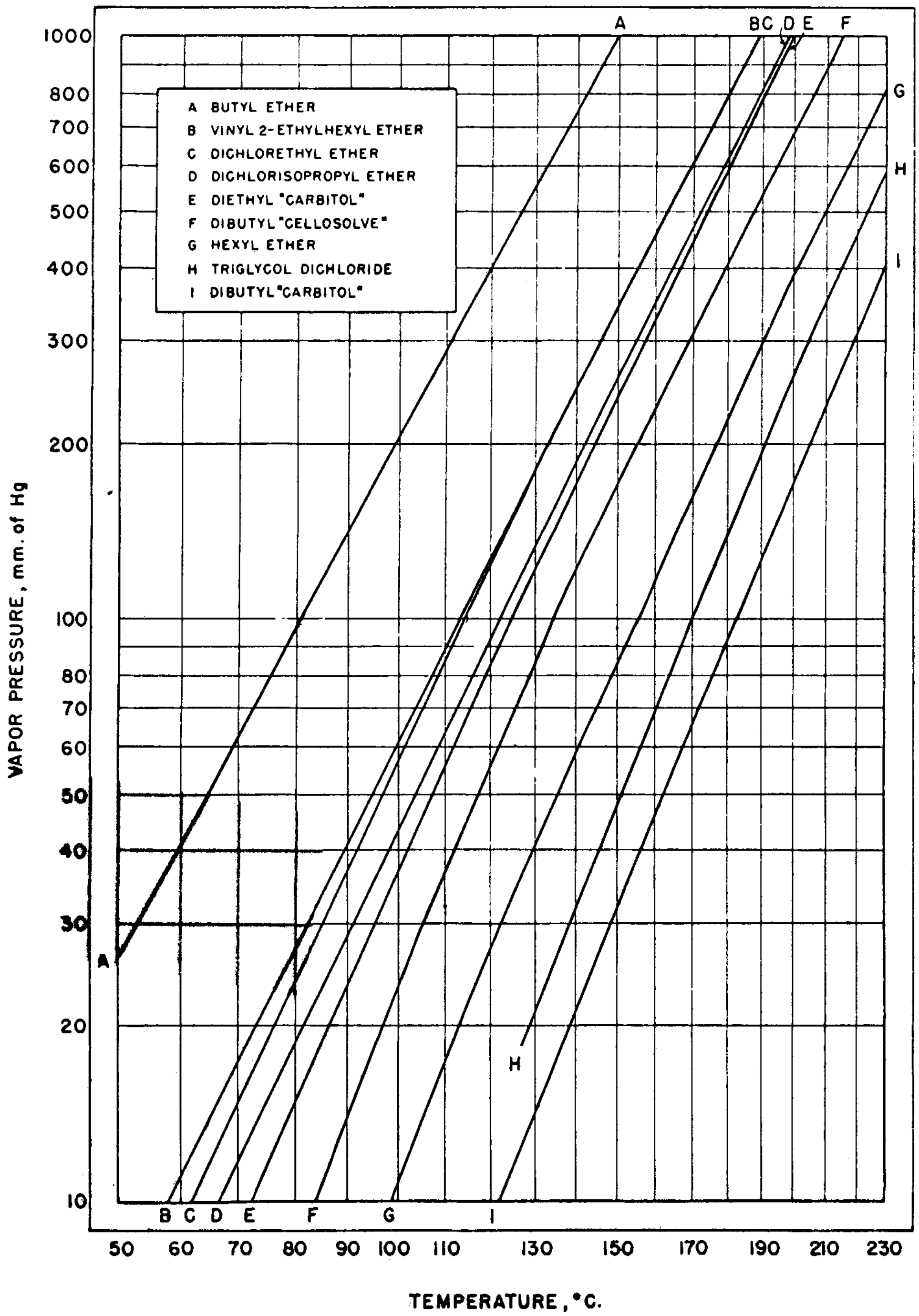


Table 10.23: Vapor Pressure of Various Ethers *(19)*



(continued)

Table 10.23: (continued)

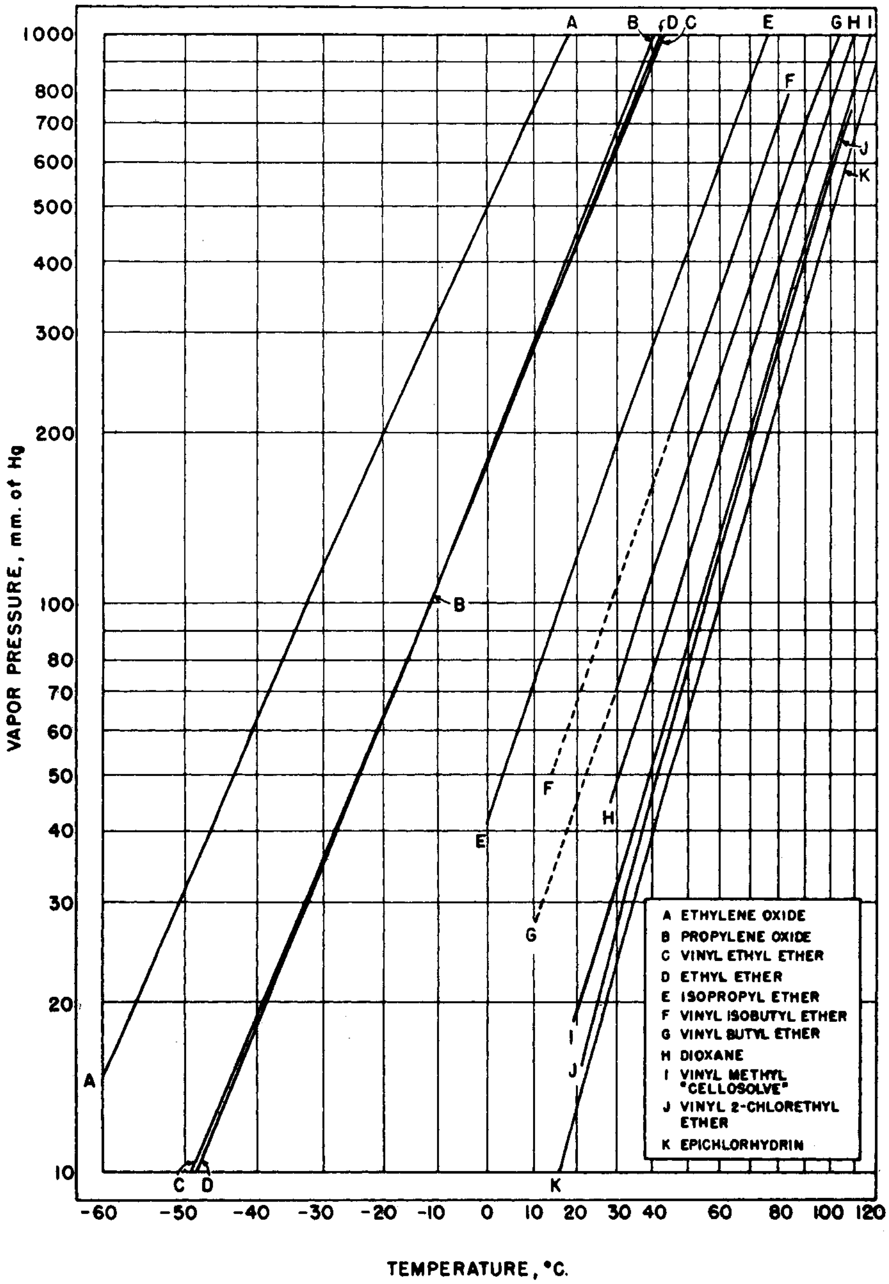
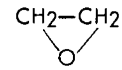


Table 10.24: Ethylene Oxide *(2)*

Epoxyethane
Dimethylene Oxide



Acidity (as acetic acid), % by wt.	0.005 (max.)
Boiling point, °C.	
760 mm.	10.4
50 mm.	-44
10 mm.	-66
Δ bp/Δ p, °C./mm. Hg	0.033
Coefficient of expansion at 55°C.	0.00177
Flash point (open cup), °F.	below 0
Freezing point, °C.	-112.5
Heat of vaporization (Btu/lb. at 1 atm.)	245
Molecular weight	44.05
Refractive index (n_D at 7°C.)	1.3597
Solubility, % by wt. at 20°C.	
in water	infinite
water in	infinite
Specific gravity, 20/20°C.	0.8711
ΔSG/Δ T	0.00140
Specific heat at 20°C.	0.8763
lb./gal. at 60°F.	7.30
Vapor pressure, mm. Hg at 20°C.	1120
Viscosity (absolute) in centipoises, 0°C.	0.3

Table 10.25: Enthalpy and Entropy of Ethylene Oxide *(19)*

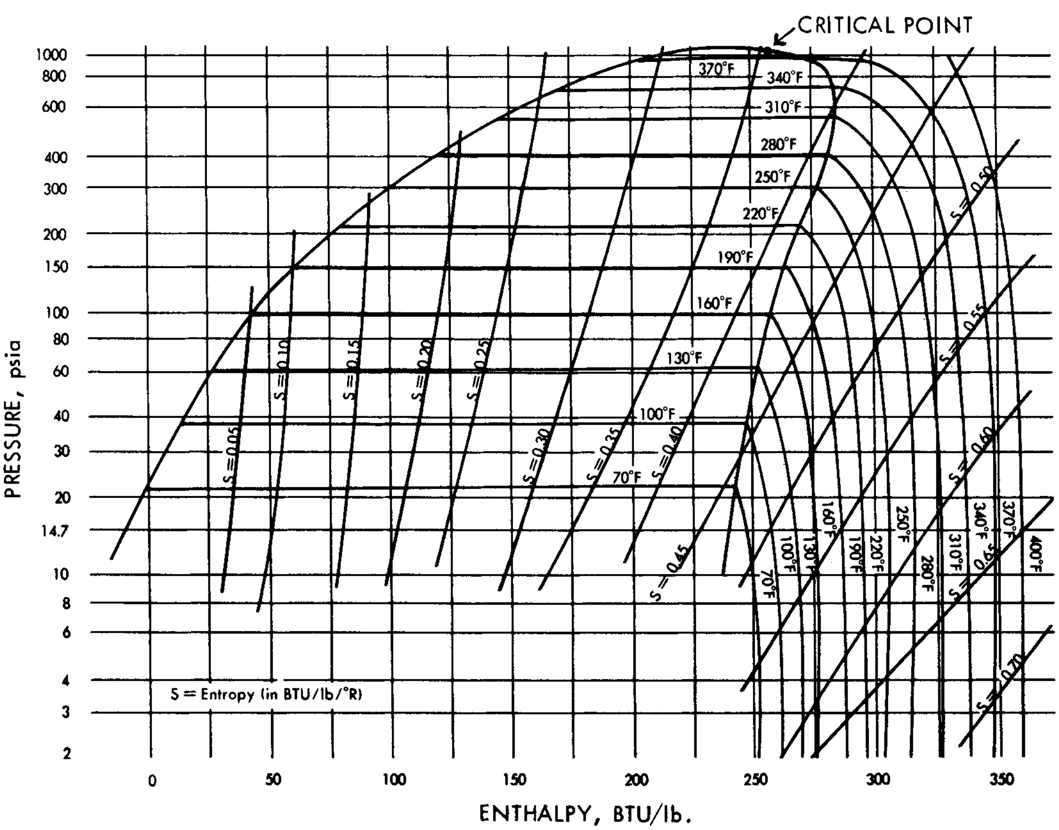
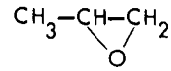


Table 10.26: Propylene Oxide *(2)*

1,2-Epoxypropane



Propylene oxide is soluble in water and miscible with most organic solvents. It is found to be an excellent low-boiling solvent for cellulose acetate, nitrocellulose, adhesive compositions and vinyl chloride-acetate resins. It is also a solvent for hydrocarbons, gums and shellac. Some of its uses are as a solvent and stabilizer in DDT aerosol-type insecticides, and as a fumigant and food preservative. Since it is an acid acceptor, it is also used as a stabilizer for vinyl chloride resins and other chlorinated systems.

Acidity (as acetic acid), % by wt. (max.)	0.01
Boiling point, °C.:	
760 mm. Hg	34.0
50 mm. Hg	-26
10 mm. Hg	-52
Δ BP/Δ P., °C./mm. Hg	0.037
Coefficient of expansion at 55°C.	0.00157
Distillation at 760 mm., °C.:	
Initial BP/min.	33.0
DP, max.	37.0
Flash point (open cup), °F.	-35
Freezing point, °C.	-104.4
Heat of vaporization (Btu/lb. at 1 atm.)	160
Molecular weight	58.08
Refractive index (n_D at 20°C.)	1.3657
Solubility, % by wt. at 20°C.:	
in water	40.5
water in	12.8
Specific gravity, 20/20°C.	0.8304
SG/T.	0.00125
Specific heat at 15°C.	0.465
lb./gal. at 60°F.	6.96
Vapor pressure, mm. Hg at 20°C.	449
Viscosity (absolute) in centipoises, 20°C.	0.4

Table 10.27: Freezing Points of Solutions of Ethylene Oxide and Propylene Oxide *(19)*

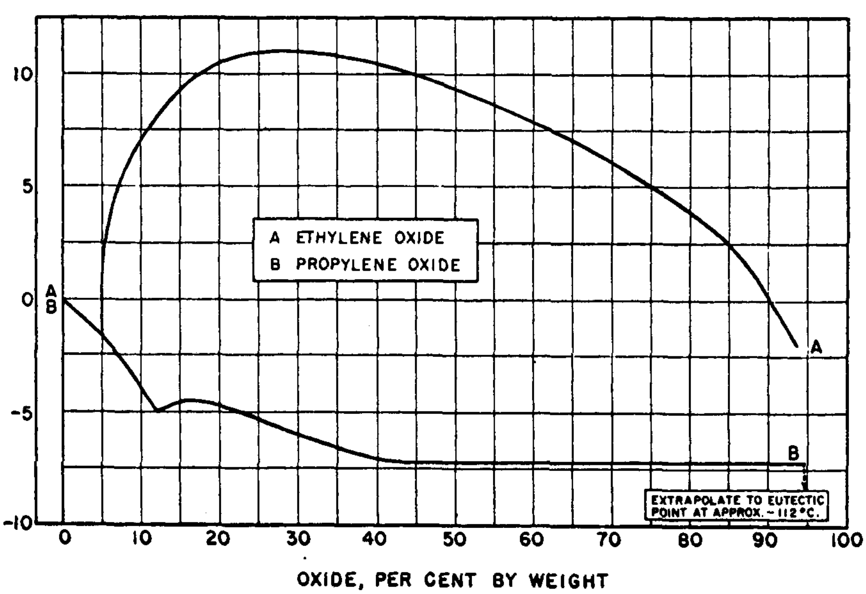
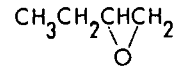


Table 10.28: 1,2-Butylene Oxide *(2)*

1,2-Epoxybutane

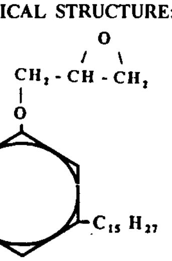


1,2-Butylene oxide is a colorless mobile liquid. This low boiling liquid has but limited water solubility, yet is miscible with most common organic solvents. It undergoes the usual reactions of epoxides with compounds having labile hydrogen atoms. Some of these are acids, amines, ammonia, alcohols, phenols, polyols, thiols, etc. Butylene oxide can be polymerized or copolymerized with other alkylene oxides to yield polyethers. The resulting polymers are less water soluble than the polymers made from ethylene and propylene oxide, of equivalent chain length.

Boiling point, °C. at 760 mm.	63.2
Coefficient of expansion at 20°C.	0.00132
Freezing point, °C.	-150
Heat of combustion (Btu/lb. at 25°C.)	14,665
Heat of vaporization (Btu/lb. at 1 atm.) and 63.2°C.	181
Molecular weight	72.11
Refractive index (n_D at 20°C.)	1.3840
Solubility, % by wt. at 20°C.:	
in water	5.91
water in	2.65
Surface tension at 20°C., dynes/cm.	23.9
Vapor pressure, mm. Hg at 20°C.	141
Viscosity (absolute) in centipoises:	
0°C.	0.54
20°C.	0.41
40°C.	0.33

Table 10.29: CARDOLITE NC-513: *(71)*

CHEMICAL STRUCTURE:



TYPICAL PROPERTIES:

	Typical value	Specification
Viscosity @ 25°C [cPs]	50	40-70
Epoxy equivalent weight [EEW]	490	424-575
Flash point (closed cup)	400°F/205°C	-
Density @ 25 °C [lbs/gal (kg/l)]	8.17 (0.97)	-
Color [Gardner]	<13	-
Appearance	reddish brown liquid	-
Hydrolyzable Chlorine	-	< 2 %
Recommended PHR (liquid epoxy resins, EEW = 190)	2-20	-

DESCRIPTION:

Cardolite® NC-513 is a unique reactive epoxy flexibilizer and diluent. This low viscosity fluid has predominantly one reactive epoxy group per molecule which combines chemically into the epoxy system.

APPLICATIONS:

- Flexibilization of solvent free and high solids surface tolerant marine and industrial coatings.
- Industrial flooring requiring excellent chemical-, water- and abrasion resistance.
- Preparation of amine adducts.
- **Coatings in contact with potable water (NSF approval)**

ADVANTAGES:

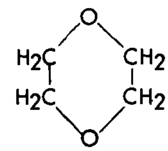
- Excellent chemical and water resistance
- Increased thermal shock resistance
- Maintains electrical properties
- Low volatility
- Aids in Bis-Phenol F resin and Curing Agent compatibility

REGULATIONS :

- United States Department of Agriculture acceptance.
- National Sanitation Foundation (NSF), coatings for use with potable water; NC-513 is being used in coatings that have NSF approval.
- Ozone Depleting Chemicals-certification that products are not classified as / are not manufactured with Class I or Class II ozone depleting chemicals.

Table 10.30: 1,4-Dioxane *(2)*

1,4-Dioxan
1,4-Diethylene Oxide
Dioxyethylene Ether
Diethylene Ether
Diethylene Dioxide

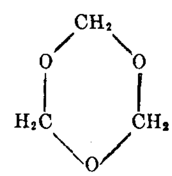


1,4-Dioxane is a colorless, stable liquid with a faint, pleasant odor. Although it has been known as far back as 1863, it was not until 1929 that is became commercially available. It is chemically a di-ether obtained by the loss of water from two molecules of ethylene glycol. It is completely soluble in water, as well as most organic solvents. It is freely soluble in mineral, vegetable, blown and heat-bodied oils, and oil soluble dyes. Most waxes are more readily soluble in dioxane when heated and examples of these are beeswax, carnauba, montan, paraffin, gilsonite, and Japan wax.

Acidity (as acetic)	0.010% by wt, max
Boiling point 760 mm	101.3°C
Distillation range at 760 mm	95-103°C
Coefficient of expansion	0.001030 (per °C) to 20°C
	0.001070 (per °C) to 55°C
Electrical conductivity at 25°C	2×10^{-9} recip. ohms
Flash point	65°F
Freezing point	11.7°C
Heat of combustion	581 kg cal/mol
Heat of fusion	33.8 cal/g
Heat of vaporization	98.6 cal/g
Refractive index at 20°C	1.4221
Specific gravity at 20/20°C	1.0356
	1.0353
Specific heat at 20°C	0.420 cal/g
Surface tension at 25°C	36.9 dynes/cm
Solubility in water at 20°C	Complete
Solubility of water in dioxane at 20°C	Complete
Viscosity at 25°C	0.0120 poise
Vapor pressure at 20°C	29.0 mm Hg
Water content at 20°C	Miscible without turbidity with 19 vol. 60° Be gasoline
Weight per gal at 20°C	8.61 lbs

Table 10.31: Trioxane *(2)*

Cyclic Trimeric Polymer of Formaldehyde



Trioxane is a most unusual chemical. It is an excellent solvent for many classes of materials. Concentrated aqueous solutions of trioxane have solvent properties which are not possessed by trioxane itself. Molten trioxane dissolves numerous organic compounds, such as naphthalene, urea, camphor, dichlorobenzene, etc. It is stable in alkaline or neutral solutions, yet it is depolymerized to formaldehyde by small amounts of strong acid or acid-forming materials, and the rate of depolymerization can be readily controlled.

Properties

Colorless, crystalline compound	
Molecular weight	90.05
Odor	Mild, pleasant
Melting point	61°C
Boiling point	115°C
Vapor Pressure:	
25°C	13 mm
86°C	283 mm
114.5°C	759 mm
129°C	1212 mm
Flash point	45°C
Density (molten) at 65°C	1.170

Solubility:	
Water	Readily soluble
Alcohols	Readily soluble
Ketones	Readily soluble
Ethers	Readily soluble
Esters	Readily soluble
Chlorinated hydrocarbons	Readily soluble
Aromatic hydrocarbons	Readily soluble
Vegetable oils	Readily soluble
Naphthalene	Readily soluble
Phenol	Readily soluble
Petroleum ether	Slightly soluble

Table 10.32: Vinyl Methyl Ether *(2)*

$CH_2{=}CHOCH_3$

Vinyl methyl ether is a gas at ordinary temperature and pressure. When condensed it is a colorless, mobile liquid having a vapor pressure at 760 mm. at 5.5°C. It is miscible with most organic solvents, but only slightly soluble in water or polyhydroxy organic compounds such as glycols. In volatility and flammability it resembles liquefied petroleum gases.

Boiling point, 760 mm.	5.5°C.	Solubility of water in ether at 25°C.	0.51% by wt.
Flash point (Cleveland open cup)	-69°F. (-56°C.)	Specific gravity at 5.7/4°C.	0.7694
Freezing point	-122°C.	Specific gravity at 20/4°C.	0.7511
Molecular weight	58.08	Vapor pressure at 25°C.	1550 mm. Hg
Odor	Sweet, pleasant	Vapor pressure at 70°F.	28 psi abs.
Refractive Index	1.3947	Weight per gallon at 25°C.	6.17 lbs.
Solubility in water at 25°C.	0.82% by wt.		

Table 10.33: Vinyl Ethyl Ether *(2)*

$CH_2{=}CHOCH_2CH_3$

Boiling point, °C.:		Molecular weight	72.10
760 mm.	35.5	Refractive index (n_D at 20°C.)	1.3774
50 mm.	-24	Solubility, % by wt. at 20°C.:	
10 mm.	-49	in water	0.9
Δ BP/Δ P., °C./mm. Hg	0.038	water in	0.2
Coefficient of expansion at 55°C.	0.00165	Specific gravity, 20/20°C.	0.7541
Flash point (open cup), °F.	below 0	Δ SG/Δ T.	0.00117
Freezing point, °C.	-115.3	Vapor pressure, mm. Hg at 20°C.	428
Heat of vaporization (Btu/lb. at 1 atm.)	161	Viscosity (abs.) in centipoises, at 20°C.	0.2

Table 10.34: Vinyl 2-Chloroethyl Ether *(2)*

$CH_2{=}CHOCH_2CH_2Cl$

Boiling point, °C.:		Solubility, % by wt. at 20°C.:	
760 mm.	109.1	in water	0.6
50 mm.	39	water in	0.4
10 mm.	10	Specific gravity, 20/20°C.	1.0498
Δ BP/Δ P., °C./mm. Hg	0.044	Δ SG/Δ T.	0.00123
Coefficient of expansion at 55°C.	0.00118	Vapor pressure, mm. Hg at 20°C.	18.6
Flash point (open cup), °F.	90	Viscosity (abs.) in centipoises:	
Freezing point, °C.	-69.7	0°C.	1.1
Heat of vaporization (Btu/lb. at 1 atm.)	154	20°C.	0.8
Molecular weight	106.55	40°C.	0.6
Refractive index (n_D at 20°C.)	1.4381		

Table 10.35: Vinyl Butyl Ether *(2)*

$CH_2{=}CHOC_4H_9$

Boiling point, °C.:		Molecular weight	100.16
760 mm.	94.2	Refractive index (n_D at 20°C.)	1.4007
50 mm.	24	Solubility, % by wt. at 20°C.:	
10 mm.	-4	in water	0.30
Δ BP/Δ P., °C./mm. Hg	0.044	water in	0.09
Coefficient of expansion at 55°C.	0.00133	Specific gravity, 20/20°C.	0.7803
Flash point (open cup), °F.	15	Δ SG/Δ T.	0.00100
Freezing point, °C.	-112.7	Vapor pressure, mm. Hg at 20°C.	40.4
Heat of vaporization (Btu/lb. at 1 atm.)	137	Viscosity (abs.) in centipoises, 20°C.	0.5

Table 10.36: Vinyl Isobutyl Ether *(2)*

$CH_2{=}CHOCH_2CH(CH_3)_2$

Boiling point, °C.:		Refractive index (n_D at 20°C.)	1.3961
760 mm.	83.4	Solubility, % by wt. at 20°C.:	
50 mm.	17	in water	0.2
10 mm.	-7	water in	0.08
Δ BP/Δ P., °C./mm. Hg	0.045	Specific gravity, 20/20°C.	0.7706
Coefficient of expansion at 55°C.	0.00140	Δ SG/Δ T.	0.00104
Flash point (open cup), °F.	15	Specific heat at 15°C.	0.512
Freezing point, °C.	-132.3	Vapor pressure, mm. Hg at 20°C.	59.5
Heat of vaporization (Btu/lb. at 1 atm.)	144	Viscosity (abs.) in centipoises, at 20°C.	0.4
Molecular weight	100.16		

Table 10.37: Vinyl 2-Ethylhexyl Ether *(2)*

$CH_2{=}CHOCH_2CH(C_2H_5)C_4H_9$

Boiling point, °C.:		Refractive index (n_D at 20°C.)	1.4273
760 mm.	177.7	Solubility, % by wt. at 20°C.:	
50 mm.	95	in water	0.01
10 mm.	62	water in	0.05
Δ BP/Δ P., °C./mm. Hg	0.053	Specific gravity, 20/20°C.	0.8102
Coefficient of expansion at 55°C.	0.00107	Δ SG/Δ T.	0.00084
Flash point (open cup), °F.	135	Vapor pressure, mm. Hg at 20°C.	0.60
Freezing point, °C.	100*	Viscosity (abs.) in centipoises:	
Heat of vaporization (Btu/lb. at 1 atm.)	129	0°C.	1.5
Molecular weight	156.26	20°C.	1.0

*Sets to a glass below this temperature

Table 10.38: Typical Properties of the Vinyl Ethers *(49)*

Vinyl Ether	Melting Point °C	Boiling Point Temp. °C	at mm Hg Pressure	Flammability °F
Methyl	-122°	5-6°	760	-69° (a)
Isopropyl	-140°	55-56°	760	-
Isobutyl	-112°	25° 83°	77 760	20° (a)
2-Ethylhexyl	-100°	62-64° 178°	18 760	-
Isooctyl	-80°	80° 175-6°	25 760	140° (a)
Decyl	-41°	60-98°	5	185° (a)
Cetyl	16°	142° 173°	1 5	325° (a)
Octadecyl	28°	124-168° 147-187°	2 5	350° (a)
Dimethylaminoethyl	-	42-44°	30	110° (b)

(a) Flash point - open cup method. (b) Fire point - ASTM D-92.

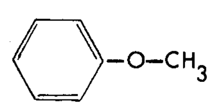
(continued)

Table 10.38: (continued)

Vinyl Ether	Refractive Index	Specific Gravity	Pounds per Gallon @ 25°C	Typical Vinyl Ether Content
Methyl	1.3947^{25}_{D}	$0.7694\ ^{5.7}_{4}$	6.17	99%
Isopropyl	$1.3849\ ^{20}_{D}$	$0.753\ ^{20}_{4}$	6.28	98%
Isobutyl	$1.3965\ ^{20}_{D}$	$0.768\ ^{20}_{4}$	6.40	98%
2-Ethylhexyl	$1.4273\ ^{20}_{D}$	$0.810\ ^{20}_{20}$	6.74	95%
Isooctyl	$1.4256\ ^{25}_{D}$	$0.802\ ^{20}_{4}$	6.66	98%
Decyl	$1.4278\ ^{25}_{D}$	$0.812\ ^{20}_{4}$	6.75	98%
Cetyl	$1.4444\ ^{25}_{D}$	$0.822\ ^{27}_{15}$	6.85	97%
Octadecyl	$1.4440\ ^{30}_{D}$	0.80 cast solid $0.821\ ^{30}_{4}$ liquid	6.84	95%
Dimethylaminoethyl	$1.4225\ ^{25}_{D}$	$0.830\ ^{20}_{20}$	6.85	99%

Table 10.39: Phenyl Methyl Ether *(2)*

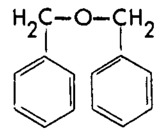
Anisole



Anisole is a high-boiling, mobile, straw-colored liquid with excellent thermal stability. It is immiscible in water and glycols but completely miscible with most common solvents. It is useful as a solvent for many organic compounds and it has unusual solvency for asphalts and pitches.

Boiling point at 760 mm. Hg, °C.	153.8
Flash point (Cleveland open cup), °F.	125
Heat of combustion, kcal./g. mol	905.2
Heat of vaporization at boiling point, cal./g. mol	8.8
Refractive index (n_D at 20°C.)	1.5165
Molecular weight	108.13
Specific gravity, 18°/4°C.	0.996
Specific heat:	
24°C.	0.422
31.6°C.	0.462
Vapor pressure, mm. Hg:	
40°C.	8.4
60°C.	25
80°C.	63
100°C.	140
120°C.	275

Table 10.40: Dibenzyl Ether *(2)*

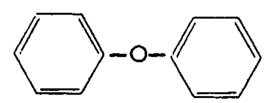


Dibenzyl ether is a clear, almost colorless liquid. It is miscible with alcohols and ethers, but insoluble in water. Dibenzyl ether is used as special solvent and delustering agent for textiles.

Boiling point, °C.:		Flash point (open cup) °F.	275
760 mm.	298	Melting point, °C.	5 (approx.)
15 mm.	165-168	Molecular weight	198.3
Distilling range, °C.:		Specific gravity, 25°/25°C.	1.041-1.045
5%	220 (min.)	Solidifying temperature, °F.	below 45
50%	300		
dry point	308		

Table 10.41: Diphenyl Oxide *(77)*

Diphenyl Ether



Diphenyl oxide is a practically colorless crystalline solid with a strong geranium-like odor. It is almost completely insoluble in water, but dissolves in most of the common organic solvents. Its high thermal stability at temperatures as high as 350° to 400°C. together with its noncorrosiveness and general chemical inertness make it eminently suitable as a component of high-boiling heat transfer media.

TYPICAL PROPERTIES

Molecular weight	170
Diphenyl oxide	>99% by weight
Crystallising point	26·6°C
Distillation range at 760 mm Hg:	
initial boiling point	253·0°C
5% by volume	254·0°C
95% by volume	256·0°C
final boiling point	260·0°C
Flash point (Pensky Martens closed cup)	240°F (115°C)
Ash	0·001% by weight
Acidity (as hydrochloric acid) ...	0·001% by weight
Water content	0·02% by weight
Phenol content	0·02% by weight

PHYSICAL PROPERTIES

The following are values for pure diphenyl oxide:

Density at 30/4°C	1·066 g/ml
Latent heat of fusion	22·9 cal/g
Specific heat at 30°C	0·40
Vapour pressure at 25°C	0·02 mm Hg
Viscosity at 25°C	3·86 cP
Refractive index n_D^{25}	1·57870

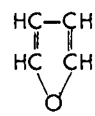
Table 10.42: Miscellaneous Alkyl Aryl Ethers *(2)*

These ethers are generally high-boiling, water insoluble liquids of pleasant odor, miscible with a variety of organic solvents and commercial oils, fats, waxes and resins.

Physical Properties

	Formula	Boiling Range °C	Flash Point °F	Sp. Gravity 20/20	Molecular Wt.
Methyl Phenyl Ether (Anisole)	$CH_3OC_6H_5$	150–160	120	0.993	
n-Butyl Phenyl Ether	$C_4H_9OC_6H_5$	202–212	180	0.929	
Amyl Phenyl Ether	$C_5H_{11}OC_6H_5$	214–229	185	0.924	164.1
p-tert-Amylphenyl Methyl Ether	$C_5H_{11}C_6H_4OCH_3$	239–243	210	0.942	
p-tert-Amylphenyl-*n*-Amyl Ether	$C_5H_{11}C_6H_4OC_5H_{11}$	285–295	260	0.905	234.2
Amyl Benzyl Ether	$C_5H_{11}OCH_2C_6H_5$	224–239	175	0.912	
Amyl Tolyl Ether	$C_5H_{11}OC_6H_4CH_3$	240–264	195	0.916	
Amyl beta Naphthyl Ether	$C_5H_{11}OC_{10}H_7$	320–350	310	1.01	
Amyl Xylyl Ether	$C_5H_{11}OC_6H_3(CH_3)_2$	250–263	205	0.907	

Table 10.43: Furan *(11)*



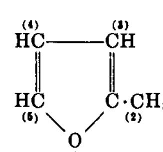
Furan is a cyclic dienic ether stabilized by benzene-like resonance. Because of its conjugated unsaturation and heterocyclic atom, furan will undergo many types of reactions. It is, therefore, of interest as a chemical intermediate for pharmaceuticals, insecticides and fine chemicals. The heterocyclic oxygen atom in a ring with conjugated unsaturation gives furan a combination of ether, aromatic and olefinic characteristics. This polyfunctionality permits it to undergo a variety of reactions. Compared to benzene, the furan ring has greater reactivity, and is more susceptible to cleavage, thus resembling the vinyl ethers. Like the vinyl ethers, the furan ring is cleaved by aqueous acids. This reaction is accompanied by resinification.

PHYSICAL PROPERTIES

Physical State	Liquid
Color	Colorless
Odor	Characteristic ethereal
Specific Gravity at 20°/4°C.	0.937
Freezing Point	-85.61°C. (-122.10°F.)
Vapor Density	0.170 lb./cu. ft.
Boiling Point (760 mm.)	31.3°C. (88.45°F.)
Flash Point (Tag. closed cup)	-32°F.
Refractive Index n20/D	1.4214
Molecular Weight	68.07
Flammability or Explosive Limits	2.3-14.3 vol. % in air
Heat of Vaporization at 31.2°C.	95.5 cal./gram
Heat of Combustion at constant vol.	500.1 kg.-cal./gram-mole
Critical Temperature	214°C.
Heat of Formation at 25°C.	-14.9 kcal./mole
Solubility in:	
	Water (wt. % at 25°C.) 1
	Most organic solvents ∞

Table 10.44: 2-Methylfuran *(2)*

Sylvan



2-Methylfuran is a cyclic diene possessing ether-like properties. It is highly reactive with many inorganic and organic compounds yielding a variety of new derivatives which await exploration for the development of commercial applications.

(continued)

Table 10.44: (continued)

Appearance	Colorless, mobile liquid
Odor	Ether-like
Molecular weight	82.098
Boiling point at 760 mm	62-64°C (144-47°F)
Freezing point	−88°C (−126.4°F)
Specific gravity, 20°C./4°C.	0.916
Index of refraction, N20/D	1.434
Flash point	−30°C (−22°F)
Vapor pressure at 15°C. (59°F)	110.5 mm
20°C. (68°F)	139 mm
25°C. (77°F)	174 mm
30°C. (96°F)	216 mm
Solubility in water at 25°C	Less than 0.3 gm/100 gm.

Table 10.45: Tetrahydrofuran *(11)(49)*

Product Information

Tetrahydrofuran (THF, tetramethylene oxide, diethylene oxide, 1,4-epoxybutane, tetrahydrofurane, oxolane) is an industrial solvent widely recognized for its unique combination of useful properties. DuPont THF is better than 99.9% pure with a small (0.025-0.040 wt %) amount of butylated hydroxytoluene (BHT, 4-methyl-2,6-di-tert-butyl phenol) added as an antioxidant. Tetrahydrofuran is a cycloaliphatic ether and is not "photochemically reactive" as defined in Section k of Los Angeles County's Rule 66 (equivalent to Rule 442 of the Southern California Air Pollution Control District). THF has an ethereal odor.

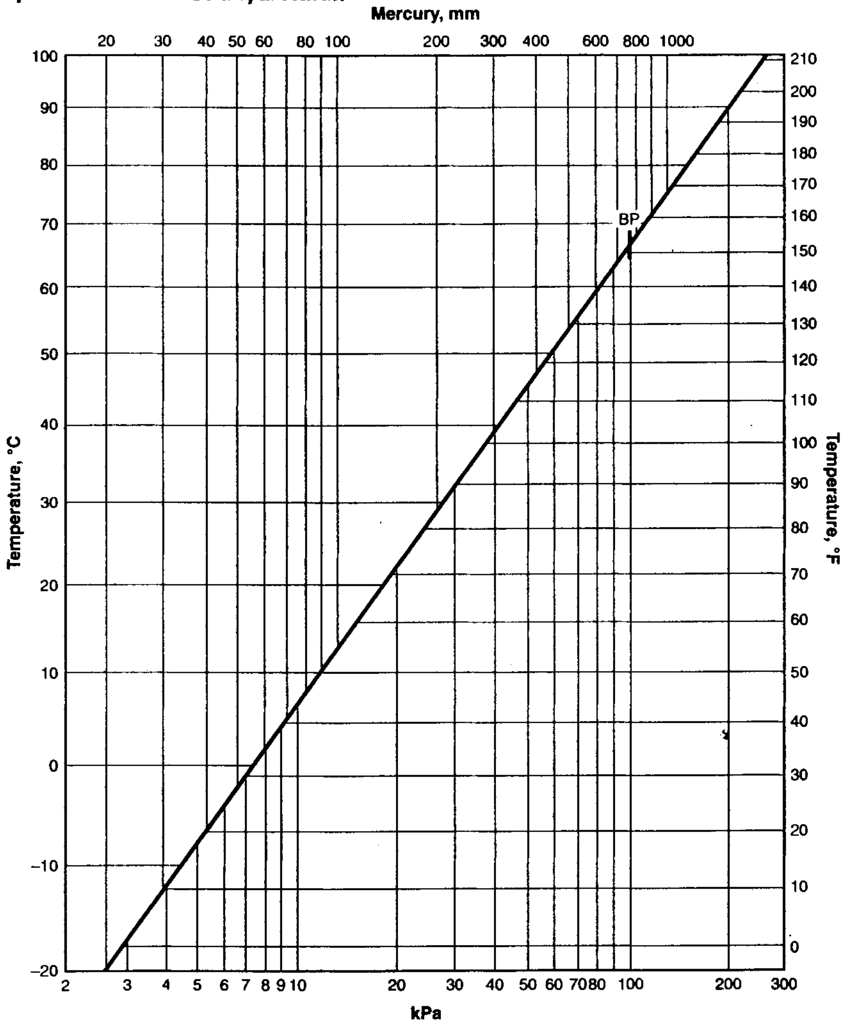
Physical Properties of Tetrahydrofuran

Molecular Weight	72.108
Boiling Point (760 mmHg), °C (°F)	66 (151)
Freezing Point, °C (°F)	−108.5 (−163)
Vapor Pressure, 20°C (68°F), mm Hg (kPa)	143 (19.1)
Density, Liquid, 20°C (68°F), g/mL (mg/m³)	0.888
lb/gal	7.41
Vapor (air = 1)	2.49
Evaporation Rate (n-butyl acetate = 1)	8.0
Viscosity, 20°C (68°F), cP (MPa·s)	0.48
Surface Tension in Air, 25°C (77°F), dyn/cm (mN/m)	26.4
Refractive Index, n_D^{20}	1.4073
Heat of Vaporization (at bp), cal/g	95
Btu/lb	171
kJ/kg	398
Heat of Combustion $(-\Delta h_c^0)$ at 25°C (77°F) liq kcal/mol	598.4
Btu/lb	14938
kJ/g	34.72
Specific Heat, Liquid, 20°C (68°F), cal/g·C (Btu/lb·F)	0.469
kJ/kg·K	1.97
50°C (122°F), cal/g·C (Btu/lb·F)	0.496
kJ/kg·K	2.090
Vapor, 66°C (151°F), cal/g·C (Btu/lb·F)	0.37
kJ/kg·K	1.55
Coefficient of Thermal Expansion, 10–20°C, av/°C	0.00126
50–68°F, av/°F	0.00070
Flash Point (TCC),°C (°F)	−14.4 (6)
Autoignition Temperature, °C (°F)	321 (610)
Flammability Limits in Air, 25°C (77°F), lower	2
upper	11.8
Critical Temperature, °C (°F)	268 (514)
Critical Pressure, atm (MPa)	51.2 (5.19)
Dielectric Constant, ε, 20°C (68°F)	7.54
30°C (86°F)	7.25
Conductivity, 25°C (77°F), μ mhos/cm	0.015
μ S/m	1.5
Dipole Moment, μ, 25–50°C (77–122°F), Debye Units	1.6
Solubility Parameter, δ	9.1
Hydrogen-Bonding Index, γ	5.3
Miscibility: water, esters, ketones, alcohols, diethyl ether; aliphatic, aromatic and chlorinated hydrocarbons	Infinite

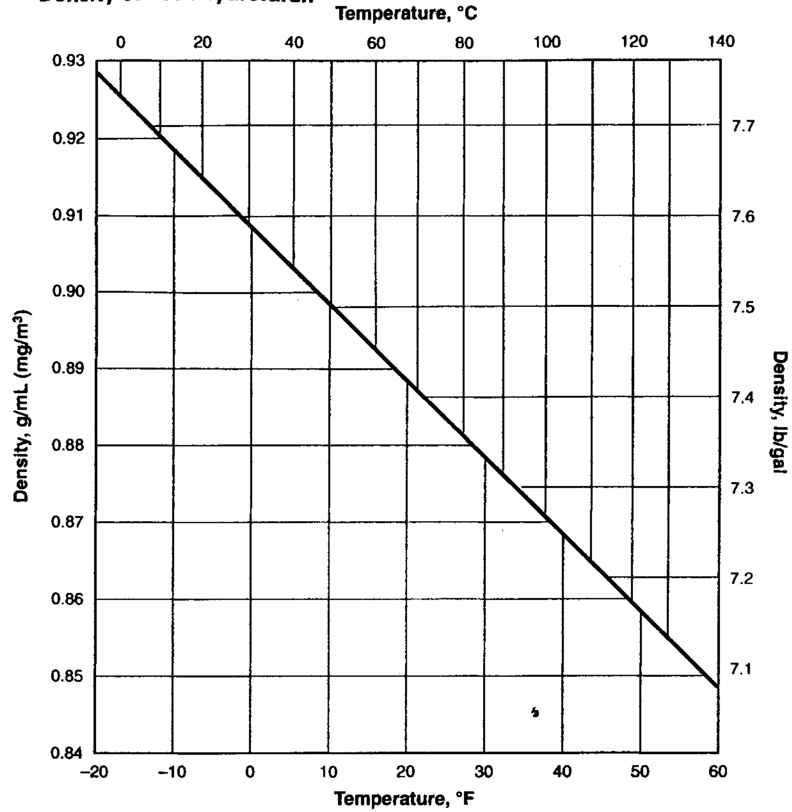
(continued)

Table 10.45: (continued)

Vapor Pressure of Tetrahydrofuran



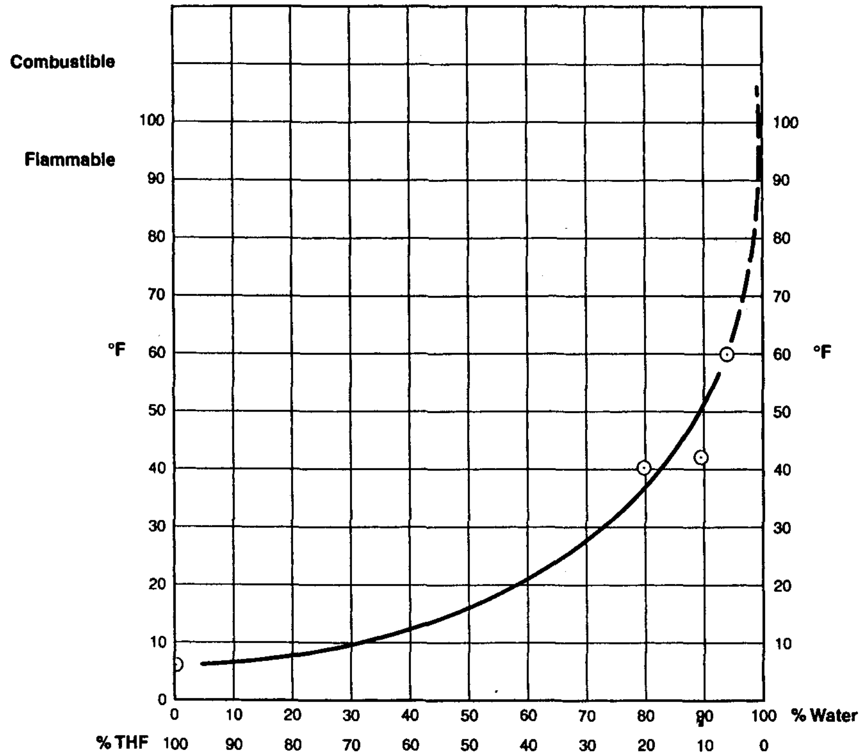
Density of Tetrahydrofuran



(continued)

Table 10.45: (continued)

Flash Points of Tetrahydrofuran-Water Solutions (by Setaflash Closed Tester)



Ref.: Culver, L. J., "Modern Paint and Coatings," Vol. 71 (1981), No. 10, pp. 145–149. (C. A. 96(10) 70460F)

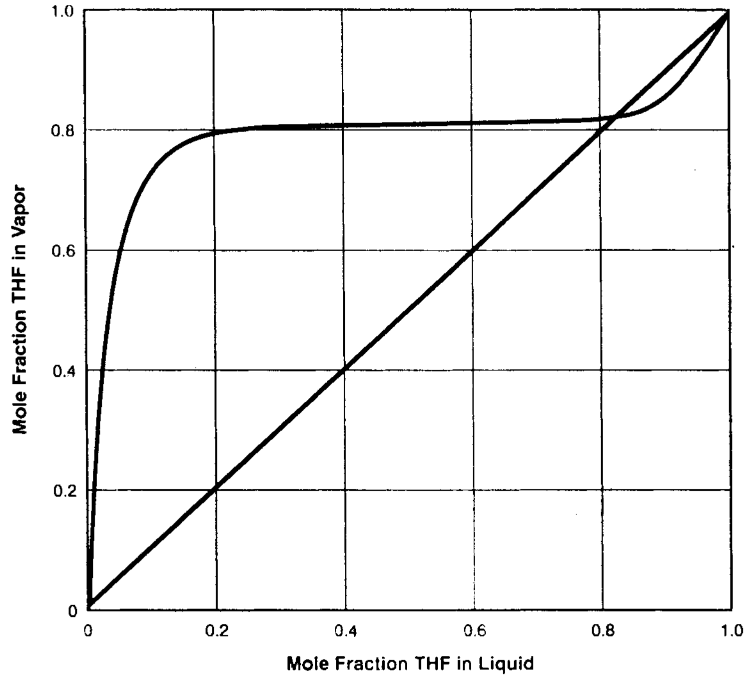
Tetrahydrofuran-Soluble Plastics, Resins, and Elastomers

Acrylic Resins	***Elastomers***
Methyl methacrylate polymers	Butadiene-acrylonitrile copolymers (some)
Ethyl, butyl, and other methacrylate polymers	Chlorinated rubbers
Acrylic polymers and copolymers	Chlorosulfonated polyethylenes
Alkyd and Amino Resins	Polysulfides
Alkyd resins	Polyurethanes (uncured)
Urea formaldehyde resins (uncured)	Rubber (natural, unvulcanized)
Phenol formaldehyde resins (uncured)	Chloroprene elastomers
Cellulosics	**Vinyl Resins**
Cellulose acetate	Polyvinyl acetate
Cellulose acetate butyrate	Polyvinyl butyrate
Cellulose acetate stearate	Polyvinyl butyrals
Ethyl cellulose	Polyvinyl chloride
Nitrocellulose	Vinyl chloride copolymers
	Vinylidene chloride copolymers
Miscellaneous Resins	Vinyl acetate/ethylene (some)
Acrylonitrile-butadiene-styrene copolymers	**Natural Resins**
Styrene-acrylonitrile copolymers	Congo ester
Chlorinated polyethylene	Coumarone-indene
Polycarbonates	Raw dammar
Polysulfones	Ester gum
Epoxy (uncured)	Manila copal
Silicones (uncured)	Pentaerythritol ester gum
Polyesters (low molecular weight)	Rosin
Polyamides (low molecular weight)	Shellac (many)
Polystyrene	
Styrene-butadiene copolymers (some)	

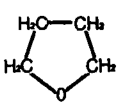
(continued)

Table 10.45: (continued)

Vapor-Liquid Equilibria of Tetrahydrofuran + Water (760 mmHg)



Chemical Structure *(49)*



Tetrahydrofuran (mol. wt. = 72.1)

C.A. No. 109999*

Other common names are:
Diethylene Oxide
1,4-Epoxybutane
Oxacyclopentane
Oxolane

The GAF product assays better than 99.8% and is stabilized with 0.025% of the antioxidant BHT (4-methyl-2,6-di-*tert.*-butyl phenol).

*SOCMA "Handbook Commercial Organic Chemical Names" Chemical Abstracts Registry Number (ACS publ.)

Typical Properties *(49)*

Physical Form	liquid
Color (APHA)	20 max
THF Assay (%)	99.8 min
Total Impurities (wt%)	0.135 max
Water Content (wt%)	0.03 max
Peroxides (as THF-hydroperoxide, wt%)	0.015 max
Stabilizer (wt%)	0.025-0.04
Other Impurities	0.05 max
Boiling Point	66°C$_{760 mm}$ (151°F)
Freezing Point	-108.5°C (-163°F)
Liquid Density (20°C)	0.888 g/cc (7.41 lb/gal)
Vapor Density (air = 1)	2.56 calc.
Specific Gravity (20/4°C)	0.886-0.889
Viscosity (20°C)	0.53 cps
Surface Tension (25°C)	26.4 dynes/cm
Refractive Index (n_D^{20})	1.4073
Coefficient of Cubical Expansion (10-20°C)	0.00129 Av/°C (0.00070 Av/°F)
Flash Point (Tag closed cup)	-14.4°C (6°F)
Flammability Limits (%/vol in air, 25°C)	2 (lower); 11.8 (upper)
Ignition Temperature	321°C (610°F)
Specific Heat (cal/g/°C) for Liquid	0.469 calc. at 20°C; 0.496 calc. at 50°C
Specific Heat (cal/g/°C) for Vapor	0.37 calc. at 66°C
Latent Heat of Vaporization (cal/g, 66°C)	98.1 calc.
Critical Temperature	268°C (514°F)
Critical Pressure	51.2 atm
Heat of Combustion (kg-cal/mole)	597 calc.
Heat of Formation (kg-cal/mole)	52.7 calc.
*Dipole Moment (25-50°C)	1.7 Debye
Dielectric Constant (20°C)	7.58
Conductivity (mhos/cm, 25°C)	1.5 x 10^{-8}
Evaporation Rate (n-butyl acetate = 1)	8.0
Solubility Parameter	9.1 calc.
Hydrogen-Bonding Index	5.3
Miscibility with water, alcohols, diethyl ether, esters, ketones, aliphatic, aromatic, and chlorinated hydrocarbons	infinite

* These data are typical of current production but are not necessarily specifications.

(continued)

Table 10.45: (continued)

High Solvent Capacity for Resins

Many THF applications are based on its solvent capacity for resins, including high-molecular-weight vinyls. For example THF is the solvent-of-choice for:

- PVC pipe welding and bonding of other molded items
- Vinyl topcoating formulations, e.g. for automobile roofs and upholstery
- Magnetic tape binder systems
- Thermoplastic polyurethane coatings
- Printing inks for plastics
- Polyurethane adhesives for shoes
- Polyester laminating adhesives
- Polymer reactor cleaning

PVC, CPVC, polyvinylidene, and vinyl chloride copolymers dissolve readily in THF at room temperature. Solutions with high solids content and workable viscosities can be prepared. Many other resins, elastomers, and uncured polyurethanes and epoxies are soluble. The list includes:

Extraction Solvent

THF is an excellent extraction solvent for many natural products, including alkaloids, fats, waxes, rubbers, and resins. The following natural resins are soluble in THF:

congo ester
coumarone-indene
ester gum
dammar
manila copal
pentaerythritol ester gum
rosin
shellac

A 66° boiling point allows refluxing in normal water-cooled systems without loss of THF; it also simplifies separation and recovery of the desired product.

Mixtures of THF and water are especially effective solvents for alkaloids, such as caffeine.

Typical Range of Resin Solubilities in THF vs MEK

Resin Type	Wt% Resin for 2500 cps, 25°C THF	MEK
Polyvinyl Chloride[1]	13-20	<3-5
Chlorinated Polyvinyl Chloride[2]	16	<5
Poly (Vinyl Chloride/Vinyl Acetate)[3]	27-40	17-22
Polyurethane[4]	17	<3
Polyvinylidene Chloride[5]	44	<3

[1]"Exon" 654 (Firestone)
"Geon" 121, 101, 103EP (Goodrich)
PVC-71 Dispersion (Diamond Shamrock)
PVC Pearls 2200, 2250 (Escambia)
"Marvinol" 10 (Uniroyal)
"Vinylite" QYNV (Union Carbide)
"Vygen" 110, 120 (General Tire)

[2]Hi-Temp "Geon" (Goodrich)

[3]"Vinylite" VYNS, VMCH, VYHH, VAGH (Union Carbide)

[4]"Estane" 5701 F-1 (Goodrich)
[5]"Saran" F-242 (Dow)

Table 10.45: (continued)

Rapid Evaporation and Diffusion Rates

When used in topcoating, printing, or other continuous operations, THF has a distinct advantage over many other solvents due to its rapid evaporation and diffusion through plastic films. This can substantially reduce costs by permitting increased machine speeds.

Solvent	Comparative Evaporation Rate
THF	800
DMF	30
1,4-Dioxane	310
Ethyl Ether	3300
MEK	570
Toluene	240
Butyl Acetate	100

The rate of diffusion of THF through PVC or polyvinylidene films is about twice that of MEK.

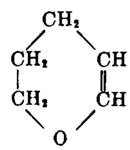
Typical Resin-Sovent Applications	Advantages of THF
Welding PVC pipe and bonding molded plastic articles.	Gives rapid, uniform bite into substrate. Can be used uncompounded as primer coat for cement. Has short set time or can be used with cosolvent to control set time. Compatible with inorganic fillers. Contributes excellent bond strength. Can be used with highest molecular weight resins for toughness. Low viscosity solutions simplify application by machine or hand. Stabilizes adhesive solutions and minimizes gelling. Redisperses accidentally gelled formulation. Rapid evaporation increases production rates.
Topcoating formulations for vinyl fabric and sheeting	Exceptional capacity for high-molecular-weight resins. Coatings are dielectric heat sealable, resistant to plasticizer migration, have good strength and durability. Can be used in solvent mixtures to stabilize the cosolvent and reduce viscosity.
Magnetic tape manufacture	Promotes uniform coating thickness when used in the binder system or in prime coats on polyester or cellulose acetate. Rapid drying. Increases production rates.
Pigmented polyurethane coatings	No effect on colors. In solutions with coalescents, produces good films for transfer coating fabric laminates employing urethane-based adhesive tie coats.
Shrink and blister packaging	Produces films with strength, clarity and uniformity; more impermeable to moisture and air than many calendered or organosol-cast films. Requires minimum amount of solvent which is easily recovered for low cost. Rapid evaporation and diffusion reduce solvent retention and bubble formation.

(continued

Table 10.45: (continued)

Typical Resin-Sovent Applications	Advantages of THF
Cellophane coating	Minimizes gelling of coating formulation. Gives high coating speeds. Improves clarity and functional properties of cast film.
Printing inks	Permits use of high-molecular-weight resins for ink toughness. Can be used in flexographic and gravure inks and for printing PVC wire insulation and vinyl sheeting or fabrics. Quick bite and rapid evaporation reduces smears.
Cleaning polymer reactors, engines, machinery; paint removers	Water flushable. Removes vinyl, polyurethane, ABS, polystyrene, and other resin deposits. Residues usually dissolve with mild agitation. Easily recovered. Can be used to improve formulations for paint removers based on nonflammable solvents. Has synergistic effect in cold cleaners.

Table 10.46: 2,3-Dihydropyran *(2)*

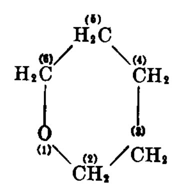


Physical Properties

	Colorless liquid with characteristic odor
Molecular weight	84.11
Boiling point	85-86°C
Sp., g. $\frac{20°C}{4°C}$	0.923

Table 10.47: Tetrahydropyran *(2)*

Pentamethylene Oxide

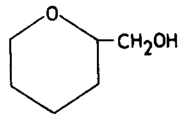


Tetrahydropyran reacts with chlorine to form mono-, di-, tri- and tetrachlorotetrahydropyrans. Reaction with acid chlorides yields omega-haloamyl esters. Conversion to dihalides such as 1,5-dibromopentane and 1,5-dichloropentane can be effected. Ammonia and aliphatic and aromatic amines yield piperidine and substituted piperidines. It is used as a solvent for resins, plastics and rubbers. Lacquers can be made by dissolving certain organic film-forming substances in tetrahydropyran. Solutions of high solids content at a working viscosity can be obtained. A solution of nitrocellulose in tetrahydropyran gives clear, nonblushing films. Tetrahydropyran is miscible with water, drying oils and most common organic solvents. The ether-like structure and ability of tetrahydropyran to dissolve a wide range of nonresinous materials suggest its use as a reaction medium for chemical processes such as Grignard reactions.

Appearance	Colorless, mobile, liquid
Odor	Ether-like
Molecular weight	86.13
Boiling point	88°C at 760 mm
Specific gravity, 20°C/4°C	0.8814
Index of refraction, N20/D	1.420
Flash point	−4°F

Solubility—Miscible with water; less soluble in hot than cold water. Miscible with alcohol, ether, and most common organic solvents.

Table 10.48: Tetrahydropyran-2-Methanol *(19)*

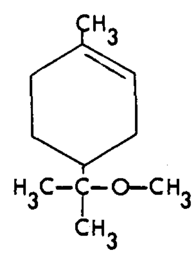


PHYSICAL PROPERTIES	Determined on specially purified sample
Molecular Weight	116.16
Apparent Specific Gravity at 20/20°C.	1.0272
Δ Sp.Gr./Δ t., 10 to 40°C.	0.00083 per °C.
True Density at 20°C.	1.0254 g. per ml.
Boiling Point	
at 760 mm. Hg	186.8°C.
at 300 mm. Hg	154°C.
at 10 mm. Hg	72°C.
Vapor Pressure at 20°C.	<0.1 mm. Hg
Δ b.p./Δ p., 750 to 770 mm. Hg	0.051°C. per mm. Hg.
Absolute Viscosity	
at 0°C.	29.3 cps.
at 20°C.	11.0 cps.
at 40°C.	5.4 cps.
Surface Tension at 25°C.	34.1 dynes per cm.
Freezing Point	-70°C. (a)
Heat of Vaporization at 1 atm.	164 Btu per lb.
at 300 mm. Hg	173 Btu per lb.
Refractive Index, n_D 20°C.	1.4581
Δ n_D/Δ t., 20 to 40°C.	0.00043 per °C.
Solubility	
In Water at 20°C.	Complete
Water In at 20°C.	Complete
Solubility in Organic Solvents at 25°C.	
acetone, benzene, ethyl ether, heptane, methanol, carbon tetrachloride	Complete
Flash Point, Cleveland open cup (ASTM Method D92)	200°F. (b)

(a) Sets to a glass below this temperature
(b) Commercial material

Table 10.49: Terpinyl Methyl Ether *(2)*

Terposol No. 3



This terpine ether known as terpinyl methyl ether is a light, colored liquid with a pleasant odor, which contains some impurities. It is a strong solvent for resins and is used in alkyd enamels to the extent of 2 per cent to which it imparts flow.

(continued)

Table 10.49: (continued)

Aniline point	Below −20°C
Color (Lovibond 500 Amber Series Glasses)	1.0
Distillation range (ASTM)	
5%	215.0°C
50%	216.5°C
90%	217.5°C
95%	218.°C
Flash point (Cleveland open cup)	178°F
Freezing point	Below −10°C
Kauri-Butanol solvency value	Approx. 500
Moisture	0.10%
Refractive index at 20°C	1.4712
Specific gravity at 15.5/15.5°C	0.9192
Viscosity at 25°C (Ubbelohde)	31.8 cp

Glycol Ethers

Table 11.1: ARCOSOLV Ethylene and Propylene Glycol Ethers *(70)*

Physical Properties

Series	ARCO TRADENAME	CHEMICAL NAME	CHEMICAL STRUCTURE	CAS#	MOL. WT.	BOILING PT. °C 760mm	SPECIFIC GRAVITY 20/20	LBS/GAL 20°C	SETA FLASH°F	EVAPORATION RATE (n-BuAc=100)
ARCOSOLV P-Series	PM	Propylene Glycol Methyl Ether	$CH_3OCH_2CHOHCH_3$	107-98-2	90.1	120	0.923	7.65	89 TCC[2]	66
	PE	Propylene Glycol Ethyl Ether	$CH_3CH_2OCH_2CHOHCH_3$	52125-53-8	104.1	133	0.902	7.50	95	47
	PNP	Propylene Glycol n-Propyl Ether	$CH_3(CH_2)_2OCH_2CHOHCH_3$	1569-01-3	118.2	150	0.887	7.38	119 TCC[2]	21
	PTB	Propylene Glycol t-Butyl Ether	$(CH_3)_3COCH_2CHOHCH_3$	57018-52-7	132.2	153	0.870	7.25	113	25
	PNB	Propylene Glycol n-Butyl Ether	$CH_3(CH_2)_3OCH_2CHOHCH_3$	5131-66-8	132.2	170	0.880	7.30	136	7
	DPM	Dipropylene Glycol Methyl Ether	$CH_3(OCH_2CHCH_3)_2OH$	34590-94-8	148.2	188	0.951	7.90	167	2
	DPNP	Dipropylene Glycol n-Propyl Ether	$CH_3(CH_2)_2(OCH_2CHCH_3)_2OH$	29911-27-1	176.3	212	0.922	7.70	190 CC[3]	1.3
	DPTB	Dipropylene Glycol t-Butyl Ether	$(CH_3)_3C(OCH_2CHCH_3)_2OH$	132739-31-2	190.3	212	0.907	7.54	188	1.5
	DPNB	Dipropylene Glycol n-Butyl Ether	$CH_3(CH_2)_3(OCH_2CHCH_3)_2OH$	29911-28-2	190.3	229	0.912	7.58	214	0.4
	TPM	Tripropylene Glycol Methyl Ether	$CH_3(OCH_2CHCH_3)_3OH$	25498-49-1	206.3	242	0.962	8.03	232	0.2
	TPNB	Tripropylene Glycol n-Butyl Ether	$CH_3(CH_2)_3(OCH_2CHCH_3)_3OH$	55934-93-5	248.4	278	0.934	7.80	255 PMCC[4]	<.1
E-Series	EM	Ethylene Glycol Methyl Ether	$CH_3OC_2H_4OH$	109-86-4	76.10	124	0.966	8.04	105 TCC[2]	53
	EE	Ethylene Glycol Ethyl Ether	$C_2H_5OC_2H_4OH$	110-80-5	90.12	134	0.931	7.75	110 TCC[2]	35
	EP	Ethylene Glycol Propyl Ether	$C_3H_7OC_2H_4OH$	2807-30-9	104.15	149	0.913	7.59	120 TCC[2]	22
	EB	Ethylene Glycol Butyl Ether	$CH_3(CH_2)_3OC_2H_4OH$	111-76-2	118.17	169	0.902	7.51	143 TCC[2]	6
	EH	Ethylene Glycol Hexyl Ether	$C_6H_{13}OC_2H_4OH$	112-25-4	146.23	208	0.889	7.40	179 TCC[2]	1
	EEH	Ethylene Glycol Ethyl Hexyl Ether	$C_4H_9CH(C_2H_5)CH_2OC_2H_4OH$	1559-35-9	174.29	224	0.892	7.42	208	0.3
	DM	Diethylene Glycol Methyl Ether	$CH_3(OC_2H_4)_2OH$	111-77-3	120.15	191	1.023	8.51	191 TCC[2]	2
	DE	Diethylene Glycol Ethyl Ether	$C_2H_5(OC_2H_4)_2OH$	111-90-0	134.17	198	0.990	8.25	195 TCC[2]	2
	DP	Diethylene Glycol Propyl Ether	$C_3H_7(OC_2H_4)_2OH$	6881-94-3	148.20	202	0.963	8.04	200 TCC[2]	1
	DB	Diethylene Glycol Butyl Ether	$C_4H_9(OC_2H_4)_2OH$	112-34-5	162.23	230	0.955	7.94	232 COC[5]	0.3

[1] Developmental Product
[2] Tag Closed Cup
[3] Closed Cup
[4] Pensky-Martens Closed Cup
[5] Cleveland Open Cup

(continued)

Table 11.1: (continued)

	ARCO TRADENAME	%SOL. IN H_2O 20°C	REF. INDEX 25°C	SURF. TENSION DYNES/CM 25°C	VAPOR PRESS mmHg 20°C	Visc. cps. 25°C	HANSEN SOLUBILITY PARAMETERS: CGS HANSEN D	CGS HANSEN P	CGS HANSEN H	CGS TOTAL HANSEN	HEAT OF VAPORIZ. CAL/°C	SPECIFIC HEAT Cal/g°C 25°C	HLB DAVIES
ARCOSOLV P-Series	PM	100	1.402	27.0	8.1	1.7	7.5	3.2	7.5	11.1	107	0.58	8.3
	PE	100	1.405	29.7	4.4	1.8	7.4	2.7	6.9	10.5	98.5	0.55	7.8
	PNP[1]	100	1.410	27.0	1.8	2.3	7.6	2.4	6.5	10.3	93	0.55	7.4
	PTB	17	1.410	24.4	1.9	3.4	7.3	2.1	6.0	9.7	81.0	0.55	6.9
	PNB	6	1.416	26.3	0.62	3.1	7.5	2.1	6.0	9.8	78.5	0.63	6.9
	DPM	100	1.420	29.0	0.17	3.4	7.4	3.0	6.3	10.2	73.4	0.53	8.2
	DPNP[1]	18	1.422	25.8	0.05	4.4	7.4	2.4	5.7	9.6	74.9	0.51	7.2
	DPTB	12	1.421	26.0	0.04	4.9	7.3	2.2	5.4	9.3	67.7	0.59	6.8
	DPNB	5	1.425	28.8	0.02	4.4	7.4	2.2	5.5	9.5	61.1	0.49	6.8
	TPM	100	1.428	29.0	0.03	5.6	7.4	3.0	5.7	9.8	74.0	0.51	8.1
	TPNB	3	1.433	29.9	<0.01	8.0	7.4	2.4	5.1	9.3	59.7	0.48	6.6
E-Series	EM	100	1.4021	30.8	6.2	1.5	7.9	4.5	8.0	12.1	123.9	0.53	8.8
	EE	100	1.4076	29.3	3.8	2.1	7.9	4.5	7.0	11.5	107.5	0.56	8.3
	EP	100	1.4136	27.9	1.3	2.4	7.9	4.2	6.6	11.1			7.8
	EB	100	1.4193	26.6	0.6	6.4	7.8	2.5	6.0	10.2	88.4	0.56	7.4
	EH	1	1.4290	30.3	<1.0	5.2	9.0	2.4	7.2	11.7			6.4
	EEH	0.2	1.4361	27.6	0.08	7.0	7.8	2.0	2.5	8.4			5.4
	DM	100	1.4268	34.8	0.2	3.9	7.9	3.8	6.2	10.7	92.7	0.54	9.2
	DE	100	1.4260	32.2	0.12	4.5	7.9	3.8	6.2	10.7	84.5	0.55	8.6
	DP	100	1.4290	32.3	0.03[1]	4.1	7.8	3.5	5.5	10.2			8.2
	DB	100	1.4316	30.0	0.02	4.7	7.8	3.4	5.2	10.0	74.3	0.54	7.7

[1] Developmental Product
[2] Tag Closed Cup
[3] Closed Cup
[4] Pensky-Martens Closed Cup
[5] Cleveland Open Cup

Regulatory Information

HMIS CODES: HEALTH	FLAMM.	REACT.	PERS. PROT.	NFPA CODES: HEALTH	FLAMM.	REACT.	1990 CAAA HAP[1]	SARA TITLE III SEC. 313[1]
1	3	0	B	0	3	0	no	no
2	3	0	X	1	3	0	no	no
2	2	0	X	1	2	0	no	no
2	2	0	B	1	2	0	no	no
2	2	0	X	1	2	0	no	no
1	2	0	B	0	2	0	no	no
1	2	0	X	0	2	0	no	no
1	2	0	X	0	2	0	no	no
1	1	0	X	0	1	0	no	no
1	1	0	B	0	1	0	no	no
1	1	0	X	0	1	0	no	no
				2	2	0	yes	yes
				2	2	0	yes	yes
							yes	yes
				2	2	0	yes	yes
							yes	yes
							yes	no
				2	2	0	yes	yes
				1	1	0	yes	yes
							yes	yes
				1	1	0	yes	yes

Table 11.2: Ashland Glycol Ethers *(69)*

PRODUCT	LB./GAL. 20° C	SP. GR. 20°/20° C	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F TCC	EVAP. RATE[1]
Glycol Ether PM	7.65	0.918	117-125	243-257	91	0.66
Glycol Ether EP	7.59	0.910	149-153	301-308	120	0.22
Glycol Ether PP	7.36	0.882	150-	302-	119	0.21
Glycol Ether PTB	7.30	0.870	151-	304-	113	—
Glycol Ether EB	7.51	0.903	169-173	336-343	150	0.06
Glycol Ether PB	7.32	0.880	170-	338-	138	0.08
Glycol Ether DPM	7.92	0.851	180-193	356-379	172	0.03
Glycol Ether DM	8.51	1.023	192-196	378-385	192	0.02
Glycol Ether DE	8.25	0.991	198-205	388-401	196	$<$0.01
Glycol Ether DP	8.04	0.969	202-216	396-421	200	$<$0.01
Glycol Ether DPP	7.67	0.922	212-	414-	190	$<$0.01
Glycol Ether DB	7.94	0.954	227-235	441-455	220	$<$0.01
Glycol Ether DPB	7.63	0.915	229-	444-	212[12]	$<$0.01
Glycol Ether TPM	8.06	0.966	236-251	457-484	240	0.01
Glycol Ether TPB	7.78[11]	0.935[11]	276-	529-	277[12]	$<$0.01

[1] n-Butyl Acetate = 1   [11] 25°C   [12] Setaflash

Table 11.3: Chemcentral Glycol Ethers *(67)*

GLYCOL ETHERS		CAS	Mole Weight	% Purity Comm. Prod.	Spec. Grav. @ 25/25°C	Lbs./Gal. @ 25°C	Coeff. of Expan. Per °C	Δ Sp. Gr. Per °C	Refractive Index @ 25°C	Initial Boiling Point @ 760 mm Hg		Vapor Press. @ 25°C mm Hg	Evap. Rate vs. B. Acet. = 1
										°C	°F		
ETHYLENE GLYCOL METHYL ETHER	EM	109-86-4	76.1		0.963	8.01	.00100	.00078	1.400	124.6	255.6	9.7	0.5
ETHYLENE GLYCOL ETHYL ETHER	EE	110-80-5	90.1	99	0.928	7.73	.00099	.00070	1.406	135.5	275.9	5.3	0.2
ETHYLENE GLYCOL n-BUTYL ETHER	EB	111-76-2	118.2	99	0.900	7.49	.00097	.00066	1.417	171.1	340.0	0.88	0.1
DIETHYLENE GLYCOL METHYL ETHER	DM	111-77-3	120.1		1.018	8.47	.00091	.00068	1.424	194.1	351.4	0.18	< 0.01
DIETHYLENE GLYCOL ETHYL ETHER	**DE**	**111-90-0**	**134.2**		**0.988**	**8.22**	**.00088**	**.00064**	**1.425**	**202.0**	**395.6**	**0.13**	**< 0.01**
DIETHYLENE GLYCOL ETHYL ETHER	DE SG		Mixt.		1.026	8.55			1.427	185.0	365.0	0.10	< 0.01
DIETHYLENE GLYCOL n-BUTYL ETHER	DB	112-34-5	162.2	96	0.952	7.92	.00086	.00060	1.430	230.0	446.0	0.023	< 0.01
PROPYLENE GLYCOL METHYL ETHER	PM	107-98-2	90.1		0.919	7.65	.00107	.00076	1.402	120.1	248.2	10.9	0.66
DIPROPYLENE GLYCOL METHYL ETHER	DPM	3459-94-8	148.2		0.951	7.91	.00100	.00072	1.419	188.3	370.9	0.36	0.02
TRIPROPYLENE GLYCOL METHYL ETHER	**TPM**	**25498-48-1**	**208.3**		**0.965**	**8.03**	**.00090**	**.00064**	**1.428**	**242.4**	**468.3**	**0.022**	**< 0.01**

[a] T.C.C

GLYCOL ETHERS		Solubility % by Wt. @ 20°C		Dilution Ratio		Blush Res. % Rel. Humid. @ 82°F	Visc. 8% RS ½ Sec. NC @ 25°C cps	Pour Point °F	Flash Point Open Cup °F	Solubility Parameter
		In H_2O	Of H_2O	Toluol	Lactol					
ETHYLENE GLYCOL METHYL ETHER	EM	∞	∞	5.3	immiscible	40	61.06	−124	120	10.8
ETHYLENE GLYCOL ETHYL ETHER	EE	∞	∞	6.6	1.1	61	56.09	−148	110[a]	9.9
ETHYLENE GLYCOL n-BUTYL ETHER	EB	∞	∞	5.2	2.2	90	105.96	−103	165	8.9
DIETHYLENE GLYCOL METHYL ETHER	DM	∞	∞	4.6	immiscible	56	123.77	−121	200	9.6
DIETHYLENE GLYCOL ETHYL ETHER	**DE**	**∞**	**∞**	**6.4**	**0.6**	**75**	**144.40**	**−130**	**205**	**9.6**
DIETHYLENE GLYCOL ETHYL ETHER	DE SG	∞	∞	2.7	immiscible	76	167.17		215	9.6
DIETHYLENE GLYCOL n-BUTYL ETHER	DB	∞	∞	6.5	1.9	95	242.35	−105	230	8.9
PROPYLENE GLYCOL METHYL ETHER	PM	∞	∞	5.2	0.9	56	67.86	−142	94[a]	9.5
DIPROPYLENE GLYCOL METHYL ETHER	DPM	∞	∞	4.2	0.8	85	168.38	−117	185	8.7
TRIPROPYLENE GLYCOL METHYL ETHER	**TPM**	**∞**	**∞**	**3.1**	**0.7**	**90**	**363.67**	**−108**	**250**	**7.9**

[a] T.C.C

Table 11.4: DOWANOL Glycol Ethers and Acetates *(23)*

Nomenclature of DOWANOL Products

DOWANOL PRODUCT	CHEMICAL NAME	FORMULA	CA[1] INDEX NAME	CAS[2]NO.[3]
P-Series				
PM	Propylene Glycol Methyl Ether	$CH_3OC_3H_6OH$	2-Propanol,1-methoxy-	107-98-2
DPM	Dipropylene Glycol Methyl Ether	$CH_3O(C_3H_6O)_2H$	Propanol, (2-methoxy-methylethoxy)-	34590-94-8
TPM	Tripropylene Glycol Methyl Ether	$CH_3O(C_3H_6O)_3H$	2-Propanol, 1-[2-(methoxy-1-methylethoxy)-1-methylethoxy]-	25498-49-1
PMA	Propylene Glycol Methyl Ether Acetate	$CH_3OC_3H_6OOCCH_3$	2-Propanol,1-methoxy, -Acetate	108-65-6
DPMA	Dipropylene Glycol Methyl Ether Acetate	$CH_3O(C_3H_6O)_2OCCH_3$	Propanol, (2-methoxy-methylethoxy),-Acetate	88917-22-0
PPh	Propylene Glycol Phenyl Ether	$C_6H_5OC_3H_6OH$	2-Propanol, 1-phenoxy-	770-35-4
BC-100	Propylene-based Glycol Ether Blend			107-98-2 34590-94-8
BC-200	Propylene-based Glycol Ether Blend			107-98-2 34590-94-8
BC-300	Propylene-based Glycol Ether Acetate Blend			108-65-6 88917-22-0
E-Series				
EB	Ethylene Glycol n-Butyl Ether	$C_4H_9OC_2H_4OH$	Ethanol, 2-butoxy-	111-76-2
DB	Diethylene Glycol n-Butyl Ether	$C_4H_9O(C_2H_4O)_2H$	Ethanol, 2-(2-butoxy-ethoxy)-	112-34-5
TBH	Triethylene Glycol n-Butyl Ether and Higher Homologs	$C_4H_9O(C_2H_4O)_nH$ ($n = 3,4,5$)	Ethanol, 2-[2-(2-butoxy-ethoxy) ethoxy]-	143-22-6
DM	Diethylene Glycol Methyl Ether	$CH_3O(C_2H_4O)_2H$	Ethanol, 2-(2-methoxy-ethoxy)-	111-77-3
TMH	Triethylene Glycol Methyl Ether and Higher Homologs	$CH_3O(C_2H_4O)_nH$ ($n=3,4,5$)	Ethanol, 2-[2-(2-methoxy-ethoxy) ethoxy]-	112-35-6
EPh	Ethylene Glycol Phenyl Ether	$C_6H_5OC_2H_4OH$	Ethanol, 2-phenoxy-	122-99-6
DALPAD A	Aromatic-Based Glycol Ether	$C_6H_5OC_2H_4OH$	Ethanol, 2-phenoxy-	122-99-6

[1] Chemical Abstract Index (American Chemical Society).
[2] Chemical Abstract Service (American Chemical Society).
[3] CAS No. for major component. Refer to MSDS for detailed CAS No. listing.

(continued)

Table 11.4: (continued)

Specification Limits and Analytical Methods for DOWANOL Products

DOWANOL	Dow Method for Gas Chromatography (GC)	Assay, Wt.% (GC)	Glycol Ether, Wt.% (GC)	Distillation Range, °C at 760 mm Hg IBP-DP (ASTM D-1078)	Specific Gravity, 25/25°C (ASTM D-891)	Color, APHA, max. (ASTM D-1209)	Water, Wt.%, max. (ASTM D-1364)	% Acidity, (as Acetic Acid), max. (ASTM D-1613)
PM	ML-AM-85-1	Note 1		117-125†	0.918-0.921†	10	0.1	0.01
DPM	22345A	99		184-193†	0.945-0.957†	15	0.15	0.01
TPM				236-251	0.962-0.965	15		0.01
PMA	22477A	99	0.5	140-150†		15	0.05	0.02
DPMA	ML-AM-83-55	98	0.5			15	0.05	0.05
BC-100	22036	98.0				15	0.15	0.01
BC-200	22037	98.0				15	0.15	0.01
BC-300	09987A	98.0	0.5			15	0.05	0.02
EB				169-173	0.898-0.901	10	0.10	0.01
DB				227-235	0.950-0.954	10	0.10	0.01
DM				191-198	1.017-1.021	10	0.10	0.01

	Dow Method (for GC)	Di-Adduct Wt.%, max.	Tri-Adduct Wt.%, min.	Tetra-Adduct Wt. %, max.	Penta-Adduct Wt.%, max.	Hexa-Adduct Wt.%, max.	Total Glycol Wt.%, max.	Water, Wt.%, max.
TMH	22560A	5.0	65.0	24.0	6.0	1.0	6.0	0.2
TBH	22523A	10	53	32	8	1.5	5	0.2

	Dow Method (for GC)	Assay, Wt. %, min.	Related Compounds, Wt.%, max.	Specific Gravity, 25/25°C	Color, APHA, max.	Phenol, Wt.%, max. (Note 2)
PPh	22484	93	7		50	0.1
EPh	22399C	90	10		50	0.5
DALPAD A				1.106-1.110	25	

† Typical Property

Note 1: DOWANOL PM assay includes 1-methoxy-2-propanol, 97%, minimum, and 2-methoxy-1-propanol, 3%, maximum.

Note 2: Dow Method 22399C is used to determine phenol using 4-aminoantipyrine reagent in DOWANOL EPh.
Dow Method 22484 is used to determine phenol in DOWANOL PPh.

(continued)

Table 11.4: (continued) **Physical Properties of DOWANOL Glycol Ethers and Acetates**

Series	DOWANOL	CHEMICAL NAME	STRUCTURAL FORMULA	Molecular Wt.	Boiling Point (°C @ 760 mm Hg)	Flash Point (°F)	Evaporation Rate (nBuAc = 1.00)	Specific Gravity (25/25°C)	Lb/Gal (25°C)	Viscosity (Centistokes 25°C)	Vapor Pressure at 25°C (mm Hg)	Surface Tension (dynes/cm)	SOLVENT CONSTANTS: Hansen Solubility Parameters[1] $(MPa^{1/2} \cdot cm^3 mol^{-1})$: δ_d (non-polar)	δ_p (polar)	δ_h (hydrogen bonding)	δ_T (Total)	Solubility (ml/100ml): Solvent in Water	Water in Solvent
P-SERIES	PM	Propylene Glycol Methyl Ether	$CH_3OCH_2CHOHCH_3$	90.1	120.1	90[2]	0.71	0.917	7.65	1.9	12.5	27.7	15.6	7.2	13.6	21.9	∞	∞
	DPM	Dipropylene Glycol Methyl Ether	$CH_3O[CH_2CH(CH_3)O]_2H$	148.2	184.0	167[2]	0.02	0.950	7.91	3.6	0.55	28.8	15.1	6.8	12.6	20.8	∞	∞
	TPM	Tripropylene Glycol Methyl Ether	$CH_3O[CH_2CH(CH_3)O]_3H$	206.3	242.4	232[2]	<0.01	0.965	8.03	5.8	0.02	30.0	14.9	6.8	10.4	19.4	∞	∞
	PMA	Propylene Glycol Methyl Ether Acetate	$CH_3OCH_2CH(CH_3)OOCCH_3$	132.2	145.8	114[2]	0.34	0.966	8.03	1.1	3.7[3]	26.4	16.1	6.1	6.6	18.4	19.8	3.2
	DPMA	Dipropylene Glycol Methyl Ether Acetate	$CH_3O[CH_2CH(CH_3)O]_2OCCH_3$	190.2	209.3	186[4]	<0.01	0.976	8.12	3.0	<1.0[3]	28.6	15.1	5.3	4.3	16.6	19.4	3.5
	PnB	Propylene Glycol n-Butyl Ether	$C_4H_9OCH_2CH(CH_3)OH$	132.2	170.0	138[4]	0.08	0.884	7.37	3.5	0.6[3]	26.3	15.6	5.8	11.2	20.1	6.4	16.0
	DPnB	Dipropylene Glycol n-Butyl Ether	$C_4H_9O[CH_2CH(CH_3)O]_2H$	190.3	229.0	212[2]	0.01	0.906	7.55	5.4	0.06[3]	28.8	15.4	5.6	9.0	18.7	5.0	12.5
	TPnB	Tripropylene Glycol n-Butyl Ether	$C_4H_9O[CH_2CH(CH_3)O]_3H$	248.4	276.0	255[5]	<<0.01	0.932	7.77	7.3	<0.01[3]	29.9[6]	15.2	5.8	6.8	17.6	3.0	8.0
	PPh	Propylene Glycol Phenyl Ether	$C_6H_5OC_3H_6OH$	152.2	242.7	240[4]	<0.01	1.063	8.80	23.2	<0.01	38.1	18.7	5.7	11.3	22.6	1.1	7.0
	PnP	Propylene Glycol n-Propyl Ether	$C_3H_7OCH_2CH(CH_3)OH$	118.2	149.8	119[2]	0.21	0.885	7.38	2.2	1.7	25.9	15.5	6.2	12.4	20.8	∞	∞
	DPnP	Dipropylene Glycol n-Propyl Ether	$C_3H_7O[CH_2(CH)CH_3O]_2H$	176.2	212.0	190[2]	0.015	0.922	7.70	4.3	0.12	27.6	15.3	5.9	10.2	19.3	19	20.5
E-SERIES	EB	Ethylene Glycol n-Butyl Ether	$C_4H_9OC_2H_4OH$	118.2	171.1	150[4]	0.07	0.897	7.49	3.2	0.88	27.4	16.0	6.2	11.4	20.6	∞	∞
	DB	Diethylene Glycol n-Butyl Ether	$C_4H_9OC_2H_4OC_2H_4OH$	162.2	230.0	226[5]	0.003	0.952	7.94	5.2	0.06	30.0	16.0	7.0	10.6	20.4	∞	∞
	TBH	Triethylene Glycol Butyl Ether/Highers	$C_4H_9O(C_2H_4O)_nH$ (n=3,4,5)	231.2 Av	283.0	285[5]	<<0.01	0.996	8.30	9.2	<0.01	31.4	-	-	-	-	∞	-
	DM	Diethylene Glycol Methyl Ether	$CH_3OC_2H_4OC_2H_4OH$	120.1	194.1	197[2]	0.02	1.021	8.47	3.4	0.25	34.8	16.2	7.8	12.6	22.0	∞	∞
	TMH	Triethylene Glycol Methyl Ether/Highers	$CH_3O(C_2H_4O)_nH$ (n=3,4,5)	173.0 Av	232.0	255[5]	<<0.01	1.054	8.80	7.0	<0.01	39.1	-	-	-	-	∞	-
	EPh	Ethylene Glycol Phenyl Ether	$C_6H_5OC_2H_4OH$	138.2	245.6	250[2]	<0.01	1.104	9.20	20.5	0.007	42.0	17.8	5.3	12.3	22.3	2.3	10.8
	DALPAD A	Aromatic-Based Glycol Ether	$C_6H_5OC_2H_4OH$	138.2	245.6	250[2]	<0.01	1.104	9.20	20.5	0.007	42.0	17.8	5.3	12.3	22.3	2.3	10.8

* Trademark of The Dow Chemical Company

[1] Solubility Parameters are useful as a guide in determining the ability of a solvent or a solvent mixture to dissolve resins. A discussion of solubility parameters and the basis for these values are contained in an article by C.M. Hansen, I and EC Product Res. Devel., 8, No. 1, 2-11, March 1969. Another useful reference is a book by A.F.M. Barton entitled *Handbook of Solubility Parameters and Other Properties*, CRC Press, Boca Raton, Florida, 1991.

[2] Setaflash

[3] Vapor pressure determined at 20°C

[4] Tag Closed Cup (TCC)

[5] Pensky-Martens Closed Cup (PMCC)

[6] Surface tension determined at 20°C

Regulatory Information on Glycol Ethers as of August, 1993

	E-Series	P-Series
CERCLA[1] spill reporting requirements	1 lb	Not applicable
SARA[2] Title III release reporting required	Yes	No
VOC[3] per Title I, Clean Air Act Amendments of 1990	Yes	Yes
HAP[4] compound per Title III, Clean Air Act Amendments of 1990	Yes	No

[1]Comprehensive Environmental Response, Compensation, and Liability Act of 1980

[2]Superfund Amendment and Reauthorization Act

[3]Volatile Organic Compound, per Federal Register, Vol. 57, No. 22, 1/3/92

[4]Hazardous Air Pollutant

Table 11.5: Eastman Chemicals Glycol Ethers *(41)*

	Evaporation Rate n-BuOAc = 1	Lb/ Gal @ 20°C	Color Pt-Co Max	Specific Gravity @ 20°/20°C	Acidity, as Acetic Acid Max Wt %	Boiling Range °C	Freezing Point °C	Flash Point TCC °C (°F)	Assay Min Wt %
EE Solvent[a] (Ethylene Glycol Monoethyl Ether) $C_2H_5OC_2H_4OH$	0.30	7.75	10	0.931	0.005	134-136	-94	43 (110)	99.9
EKTASOLVE® EP Solvent (Ethylene Glycol Monopropyl Ether) $C_3H_7OC_2H_4OH$	0.20	7.59	10	0.913	0.01	149-154	<-90	49 (120)	99.6
EKTASOLVE EB Solvent (Ethylene Glycol Monobutyl Ether) $C_4H_9OC_2H_4OH$	0.06	7.51	10	0.902	0.01	169-173	-75	62 (143)	99.6
EKTASOLVE DM Solvent (Diethylene Glycol Monomethyl Ether) $CH_3(OC_2H_4)_2OH$	0.02	8.51	10	1.023	0.01	191-198	-85	88 (191)	—
EKTASOLVE DE Solvent (Diethylene Glycol Monoethyl Ether) $C_2H_5(OC_2H_4)_2OH$	0.02	8.25	10	0.990	0.01	198-204	-90	91 (195)	99.3
EKTASOLVE DE-HG Solvent[b] (Diethylene Glycol Monoethyl Ether/Ethylene Glycol) $[C_2H_5(OC_2H_4)_2OH][HOCH_2CH_2OH]$	<0.01	8.56	10	1.027	0.01	190-205	-70	96 (205)	—
EKTASOLVE DP Solvent (Diethylene Glycol Monopropyl Ether) $C_3H_7(OC_2H_4)_2OH$	0.01	8.04	10	0.963	0.01	202-216	<-90	93 (200)	99.4
EKTASOLVE DB Solvent (Diethylene Glycol Monobutyl Ether) $C_4H_9(OC_2H_4)_2OH$	0.003	7.94	10	0.955	0.01	230-235	-76	111 (232) COC	99.6
EKTASOLVE EEH Solvent (Ethylene/Diethylene Glycol 2-Ethylhexyl Ether) $C_4H_9CH(C_2H_5)CH_2OC_2H_4OH$	0.003	7.42	50	0.892	0.01	224-275	<-60	98 (208)	—

[a]*For sale outside USA only*
[b]*High gravity solvent*

NOMENCLATURE OF GLYCOL ETHERS AND GLYCOL ETHER ESTERS

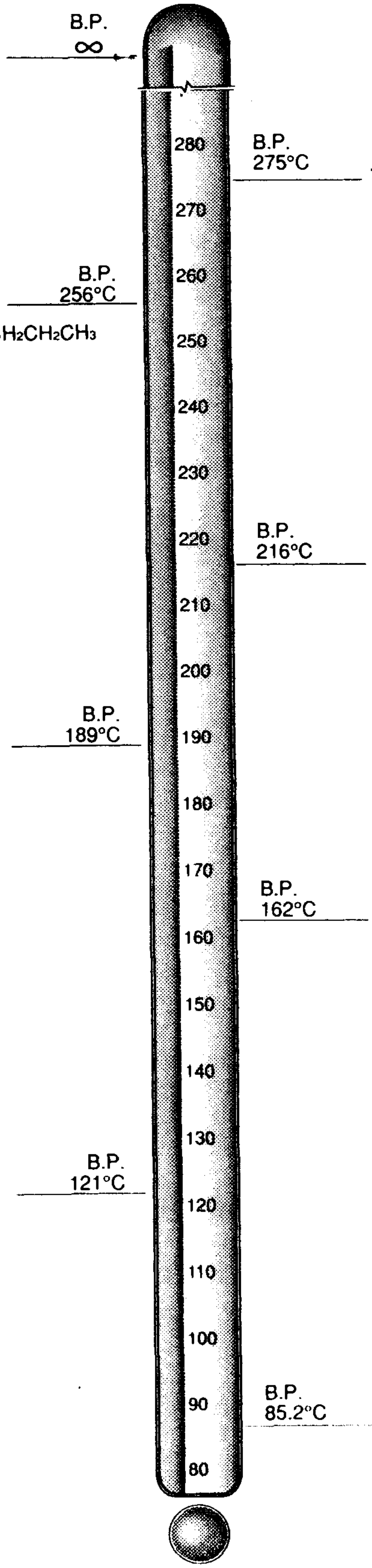
GLYCOL ETHERS

Company Name	Ethylene Glycol Propyl Ether	Ethylene Glycol Butyl Ether	Ethylene Glycol 2-Ethylhexyl Ether	Diethylene Glycol Methyl Ether	Diethylene Glycol Ethyl Ether	Diethylene Glycol Propyl Ether	Diethylene Glycol Butyl Ether	Propylene Glycol Methyl Ether
Eastman	*Eastman* EP	*Eastman* EB	*Eastman* EEH	*Eastman* DM	*Eastman* DE	*Eastman* DP	*Eastman* DB	*Eastman* PM
Union Carbide	Propyl *Cellosolve*	Butyl *Cellosolve*	—	Methyl *Carbitol*	*Carbitol* (low gravity)	Propyl *Carbitol*	Butyl *Carbitol*	Methyl *Propasol*
Dow	—	*Dowanol* EB	—	*Dowanol* DM	*Dowanol* DE	—	*Dowanol* DB	*Dowanol* PM
Shell	—	Butyl *Oxitol*	—	—	—	—	Butyl *Dioxitol*	—
Occidental	—	EB	—	—	DE	—	DB	—
Arco	—	—	—	—	—	—	—	*Arcosolv* PM

GLYCOL ETHER ESTERS

Company Name	Ethylene Glycol Butyl Ether Acetate	Diethylene Glycol Ethyl Ether Acetate	Diethylene Glycol Butyl Ether Acetate	Propylene Glycol Methyl Ether Acetate
Eastman	*Eastman* EB acetate	*Eastman* DE acetate	*Eastman* DB acetate	*Eastman* PM acetate
Union Carbide	Butyl *Cellosolve* acetate	—	Butyl *Carbitol* acetate	Methyl *Propasol* acetate
Arco	—	—	—	*Arcosolve* PM acetate
Dow	—	—	—	*Dowanol* PM acetate
Occidental	EB acetate	—	DB acetate	PM acetate

Table 11.6: Grant Chemical Glycol Diethers (GLYMES) *(21)*



POLYGLYME
CH_3-O-(CH_2CH_2-O)$_n$-CH_3
Poly(ethylene glycol) dimethyl ether
[24991-55-7]

TETRAGLYME
CH_3-O-(CH_2CH_2-O)$_4$-CH_3
Tetraethylene glycol dimethyl ether
Bis[2-(2-methoxyethoxy) ethyl] ether
Dimethoxytetraethylene glycol
2,5,8,11,14-pentaoxapentadecane
[143-24-8]

BUTYL DIGLYME
$CH_3CH_2CH_2CH_2$-O-(CH_2CH_2-O)$_2$-$CH_2CH_2CH_2CH_3$
Diethylene glycol dibutyl ether
Bis(2-butoxyethyl) ether
Dibutoxydiethylene glycol
Dibutyl Carbitol*
5,8,11-trioxapentadecane
[112-73-2]

TRIGLYME
CH_3-O-(CH_2CH_2-O)$_3$-CH_3
Triethylene glycol dimethyl ether
1,2-Bis(2-methoxyethoxy) ethane
Dimethoxytriethylene glycol
2,5,8,11-tetraoxadodecane
[112-49-2]

ETHYL DIGLYME
CH_3CH_2-O-(CH_2CH_2-O)$_2$-CH_2CH_3
Diethylene glycol diethyl ether
Bis(2-ethoxyethyl) ether
Diethoxydiethylene glycol
Diethyl Carbitol*
Ethane, 1,1'-oxybis[2-ethoxy-
3,6,9-trioxaundecane
[112-36-7]

DIGLYME
CH_3-O-(CH_2CH_2-O)$_2$-CH_3
Diethylene glycol dimethyl ether
Bis(2-methoxyethyl) ether
Dimethoxydiethylene glycol
Dimethyl Carbitol*
Ethane, 1,1'-oxybis[2-methoxy-
2,5,8-trioxanonane
[111-96-6]

ETHYL GLYME
CH_3CH_2-O-CH_2CH_2-O-CH_2CH_3
Ethylene glycol diethyl ether
1,2-Diethoxyethane
Diethoxyethylene glycol
Diethyl Cellosolve*
Ethane; 1,2-diethoxy
3,6-dioxaoctane
[629-14-1]

MONOGLYME
CH_3-O-CH_2CH_2-O-CH_3
Ethylene glycol dimethyl ether
1,2-Dimethoxyethane
Dimethoxyethylene glycol
DME
Ethane, 1,2-dimethoxy-
2,5-Dioxahexane
[110-71-4]

(continued)

Table 11.6: (continued)

Physical and Thermodynamic Properties

	EMPIRICAL FORMULA	MOLECULAR WEIGHT	BOILING POINT °C 760mm Hg	FREEZING POINT °C	SPECIFIC GRAVITY 20/20°C	WEIGHT PER GALLON lb 20°C	VAPOR PRESSURE mm Hg/20°C	VOLATILITY n-Butylacetate=100	VISCOSITY cp. 20°C	SURFACE TENSION dynes/cm. 20°C	SPECIFIC HEAT cal/gm/°C	AUTO IGNITION temp °C	HEAT OF VAPORIZATION K cal/mole	HEAT OF COMBUSTION K cal/mole	HEAT OF FORMATION K cal/mole	FLASH POINT °C, closed cup	REFRACTIVE INDEX n_D at 20°C	APPEARANCE	ODOR	SOLUBILITY at 25°C: IN WATER	SOLUBILITY at 25°C: WATER IN	SOLUBILITY at 25°C: ORGANICS
MONOGLYME	$C_4H_{10}O_2$	90.12	85.2	−69.0	0.8683	7.24	54	499	1.1	22.9	0.438	205	6.7	602	118	−6	1.3792	CLEAR COLORLESS	ETHEREAL NON-RESIDUAL	COMPLETE	COMPLETE	ALL GLYMES ARE MISCIBLE IN ALL PRO-PORTIONS IN ETHANOL, ACETONE, BENZENE, DIETHYL ETHER AND OCTANE
ETHYL GLYME	$C_6H_{14}O_2$	118.18	121	−74.0	0.8417	7.00	9	105	0.7							27	1.3922	CLEAR COLORLESS	MILD ETHEREAL NON-RESIDUAL	20.4%	3.3%	
DIGLYME	$C_6H_{14}O_3$	134.17	162	−64.0	0.9451	7.88	2	36	2.0	27.0	0.403	190	10.0	902	143	57	1.4078	CLEAR COLORLESS	MILD ETHEREAL NON-RESIDUAL	COMPLETE	COMPLETE	
ETHYL DIGLYME	$C_8H_{18}O_3$	162.23	189	−44.3	0.9082	7.56	0.5	4	1.4	27.2			10.5	1199	152	90	1.4115	CLEAR COLORLESS	MILD NON-RESIDUAL	COMPLETE	COMPLETE	
TRIGLYME	$C_8H_{18}O_4$	178.22	216	−45.0	0.9862	8.23	0.02	<0.1	3.8	29.4	0.424	195	14.3	1191	179	111	1.4224	CLEAR COLORLESS	MILD NON-RESIDUAL	COMPLETE	COMPLETE	
BUTYL DIGLYME	$C_{12}H_{26}O_3$	218.34	256	−60.2	0.8814	7.36	<0.01	<0.1	2.4	27.0	0.495	190	12.0	1823	175	118	1.4235	CLEAR COLORLESS	VERY MILD NON-RESIDUAL	0.3%	1.4%	
TETRAGLYME	$C_{10}H_{22}O_5$	222.28	275	−29.7	1.0132	8.45	<0.01	<0.1	4.1	33.8	0.427	215	18.7	1480	217	141	1.4330	CLEAR COLORLESS	VERY MILD NON-RESIDUAL	COMPLETE	COMPLETE	
POLYGLYME*	$C_nH_{2n+2}O_{n/2}$	275			1.04	8.6	<0.01	<0.1	12			215				>130		CLEAR SLIGHTLY YELLOW	VERY MILD NON-RESIDUAL	COMPLETE	COMPLETE	

* Mixture of high molecular weight glymes.

Specifications

	PURITY (by G.C.), wt %		ACIDITY (as acetic acid) ppm		WATER CONTENT ppm		PEROXIDE CONTENT ppm	
	MIN	TYPICAL	MAX	TYPICAL	MAX	TYPICAL	MAX	TYPICAL
MONOGLYME	99.90	99.97	150	25	350	175	15	5
ETHYL GLYME	97.0	98.5	150	25	1000	300	15	5
DIGLYME	99.90	99.94	150	25	250	150	15	5
ETHYL DIGLYME	98.0	99.0	150	25	2000	500	15	5
TRIGLYME	98.0	99.0	150	25	500	100	15	5
BUTYL DIGLYME	98.5	99.0	100	25	500	250	15	5
TETRAGLYME	98.0	99.0	150	25	500	100	15	5

Table 11.7: Occidental Ethylene Glycol Ethers and Glycol Ether Acetates (27)

Products, Grades and Specifications: Glycol Ethers and Acetates

SPECIFICATION*	EM	EM-J	DM	DM-J	TM	EE
Purity, weight % min	99.5				98	
Color, APHA max	10	15	10	10	50	10
Acidity (as acetic acid), wt% max	0.01		0.01		0.01	0.005
Specific gravity, 20/20°C	0.964 - 0.967	0.963 - 0.967	1.021- 1.027	1.020- 1.025	1.038- 1.058	0.929- 0.932
Distillation range, IBP, min DP, °C max	123.5 125	123.5 125.5	191.0 198.0	191.0 198.0	235.0 255.0	134 136
Water, weight % max	0.10	0.15	0.10	0.10	0.2	0.10
Acid no., mgKOH/gm, max		0.09		0.09		
Ethylene glycol, wt % max		0.025		0.5		
pH, 25% solution at 25°C		5.0 - 7.0		5.0 - 8.5	5.0 - 9.0	
Refractive index at 20°C		1.4015-1.4025				
Antioxidant (BHT), ppm		50 - 150		50 - 150		
Flash point (PMCC), °C				85		

SPECIFICATION*	DE	EB	DB	EEA	EBA	DBA
Purity, weight % min				99.0	98.0	98.0
Color, APHA max	10	10	10	15	15	15
Acidity (as acetic acid), wt% max	0.01	0.01	0.01	0.02	0.02	0.02
Specific gravity, 20/20°C	0.989 - 0.994	0.901- 0.904	0.953- 0.956	0.971- 0.976	0.940- 0.944	0.975- 0.985

Products, Grades and Specifications: Heavy Glycol Ethers

SPECIFICATION*	HM	HHM	HE	HB
Triethylene Glycol Monomethyl Ether and higher molecular wt. Monomethyl Ethers, wt % min	55.0	55.0		
Diethylene Glycol Monomethyl Ether, wt % max	10.0	2.0		
Triethylene Glycol Monoethyl Ether and higher molecular wt. Monoethyl Ethers, wt % min			70.0	
Diethylene Glycol Monoethyl Ether, wt % max			10.0	
Triethylene Glycol Monobuthyl Ether and higher molecular wt. Monobuthyl Ethers, wt % min				88.0
Diethylene Glycol Monobuthyl Ether, wt % max				12
Water, weight % max	0.1	0.1	0.1	0.1
pH, alcoholic (50/50)	7.5-11.0	7.5-11.0	7.5-11.0	7.5-11.0
Color, APHA max	100	100	100	200
Specific gravity at 20/20°C (typical)	1.03-1.06	1.04-1.06	0.99-1.06	0.984-1.002
Minimum Boiling Point °C	238	249	220	250

(continued)

Table 11.7: (continued)

Occidental Glycol Ethers and Glycol Ether Acetates

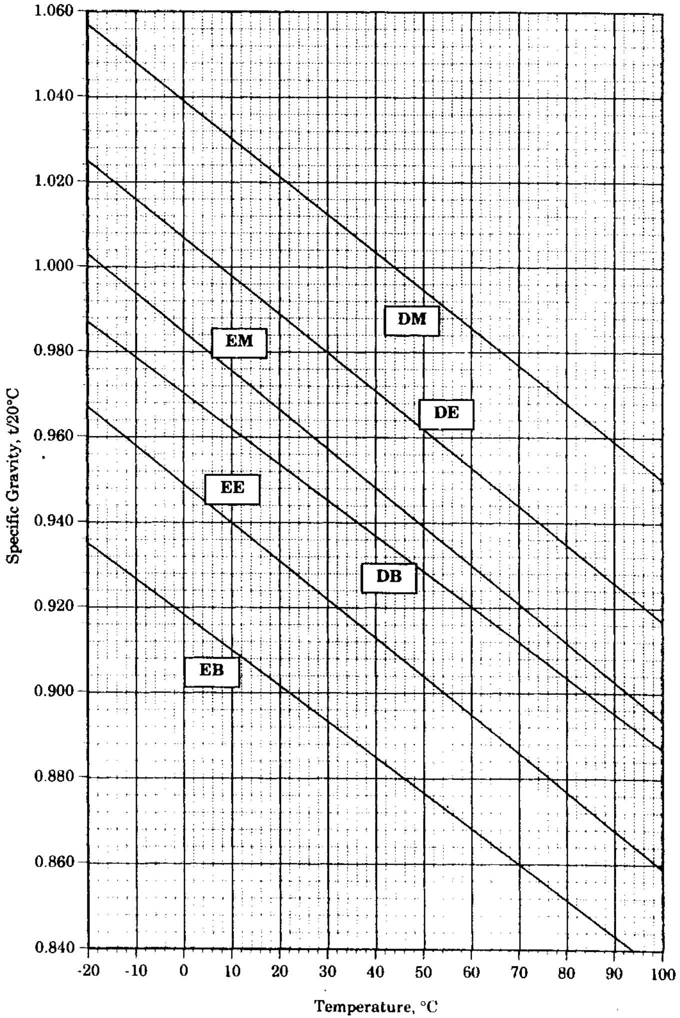
TYPICAL PROPERTIES	EM	EM-J	DM	DM-J	TM	EE
Molecular weight	76.1	76.1	120.15	120.15	164.2	90.1
Auto-ignition temp., °C	285	285	-	-	-	235
Boiling point, °C	124.2	124.5	194.0	194.0	249.0	135.5
Freezing point, °C	-85	-85	-68.9	-68.9	-44.0	-90
Flash point (TCC), °F	105	105	192	192	238	110
Surface tension @ 25°C, dynes/cm^2	30.9	30.9	35.9	35.9	38.7	28.2
Refractive index at 20°C	1.4021	1.4021	1.4263	1.4263	1.4381	1.4076
Vapor pressure at 20°C, mm Hg	6.2	6.2	0.2	0.2	<0.01	3.8
Viscosity at 20°C, cP	2.05	2.05	3.87	3.87	7.5	2.1
Coeff. of expansion at 20°C	0.00095	0.00095	0.00088	0.00088	0.00088	0.00097
Weight/gal. in lbs. at 20°C	8.04	8.04	8.51	8.51	8.74	7.75

TYPICAL PROPERTIES	DE	EB	DB	EEA	EBA	DBA
Molecular weight	134.17	118.2	162.2	132.2	160.2	204.3
Auto-ignition temp., °C	204	244	228	379	340	200
Boiling point, °C	202	171	230	156.4	-	-
Freezing point, °C	-76	-70	-68	-62	-	-
Flash point (TCC), °F	196	150	214	126	165	240
Surface tension @ 25°C, dynes/cm^2	31.8	27.4	30.0	-	-	-
Refractive index at 20°C	1.4297	1.4193	1.4316	1.4030	1.4200	1.4200
Vapor pressure at 20°C, mm Hg	0.1	< 1	< 0.1	2.0	0.25	0.04
Viscosity at 20°C, cP	4.5	6.4	6.5	1.3	1.8	3.6
Coeff. of expansion at 20°C	0.00090	0.00092	0.00085	0.00109	0.00100	0.00097
Weight/gal. in lbs. at 20°C	8.25	7.52	7.95	8.11	7.85	8.16

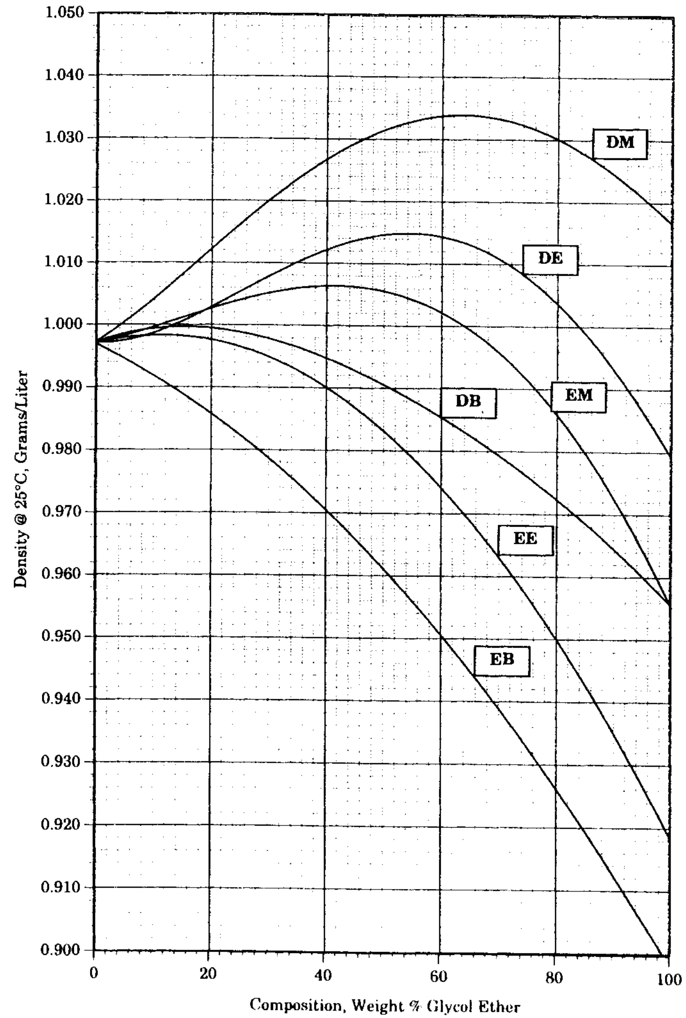
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Table 11.7: (continued)

Specific Gravity vs Temperature of the Glycol Ethers



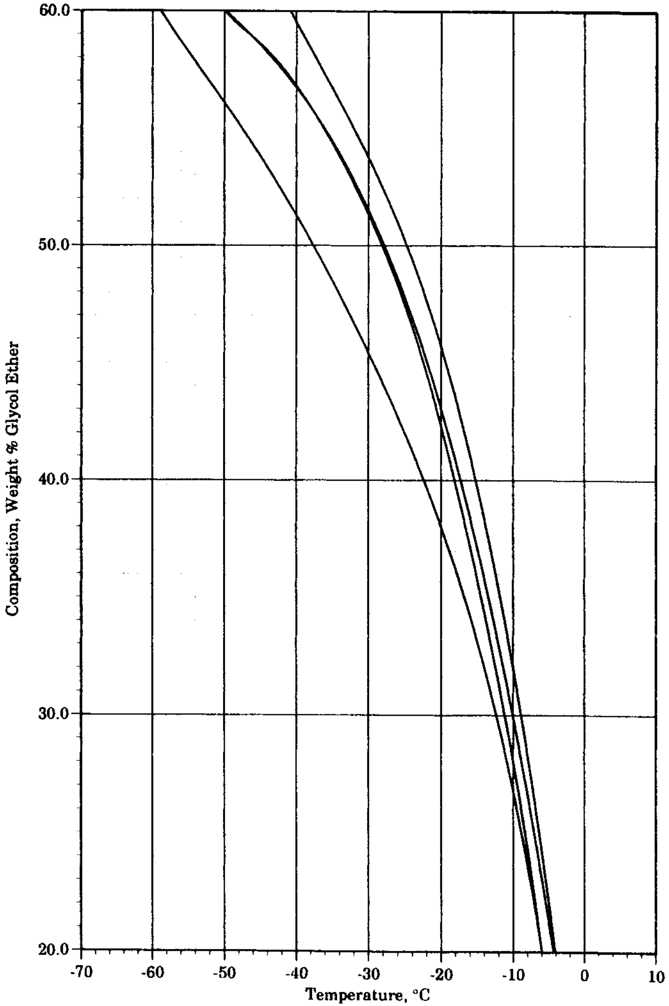
Density vs Composition of Aqueous Glycol Ether Solutions



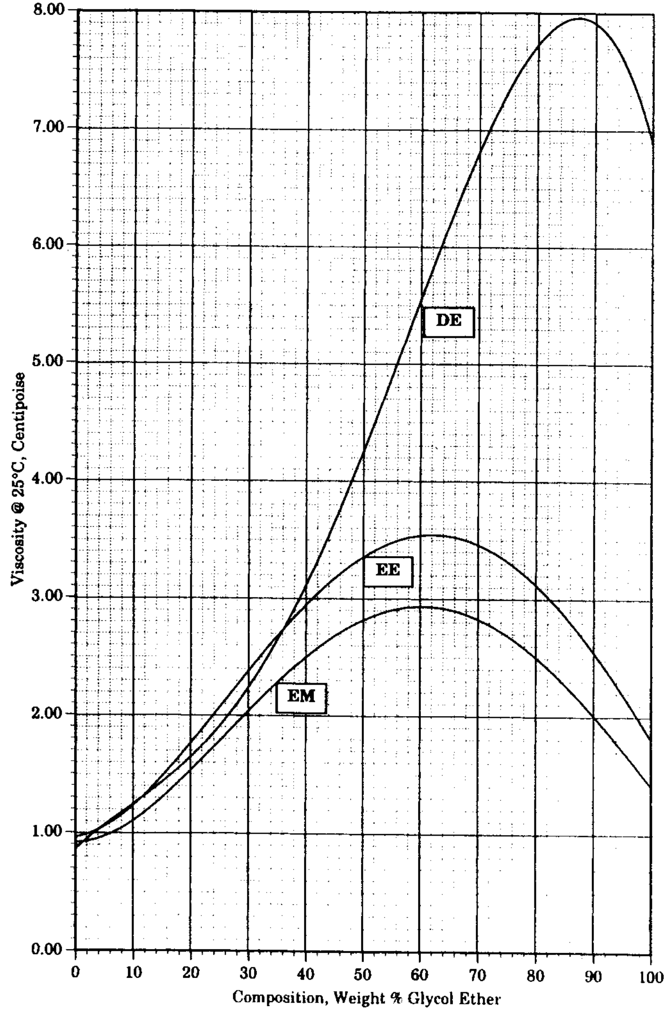
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Table 11.7: (continued)

Freezing Point vs Composition of Aqueous Glycol Ether Solutions



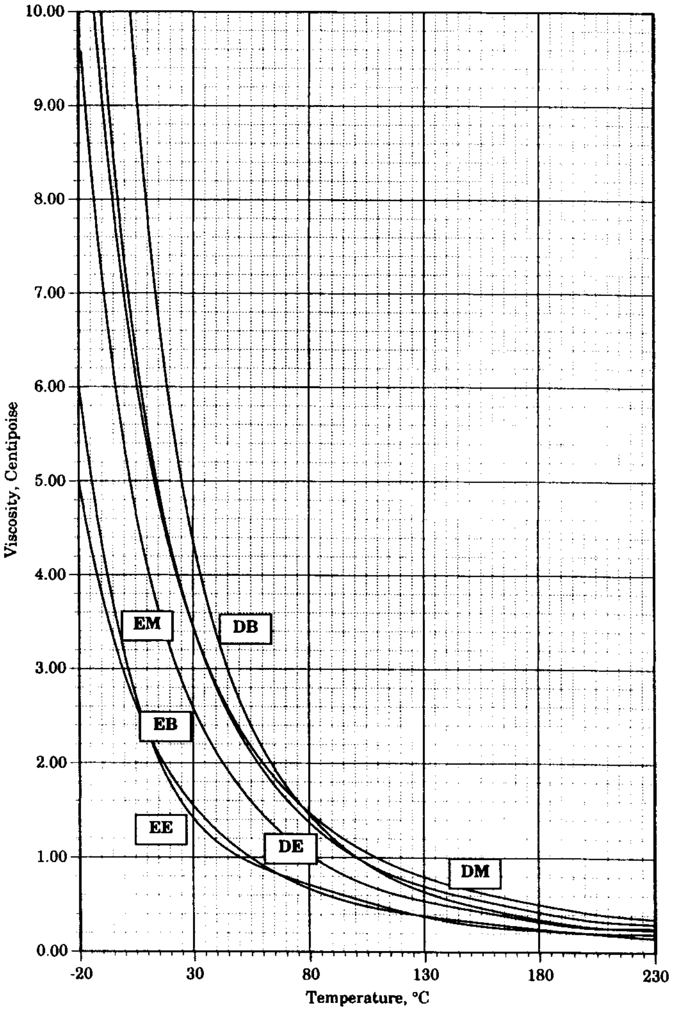
Viscosity vs Composition of Aqueous Glycol Ether Solutions



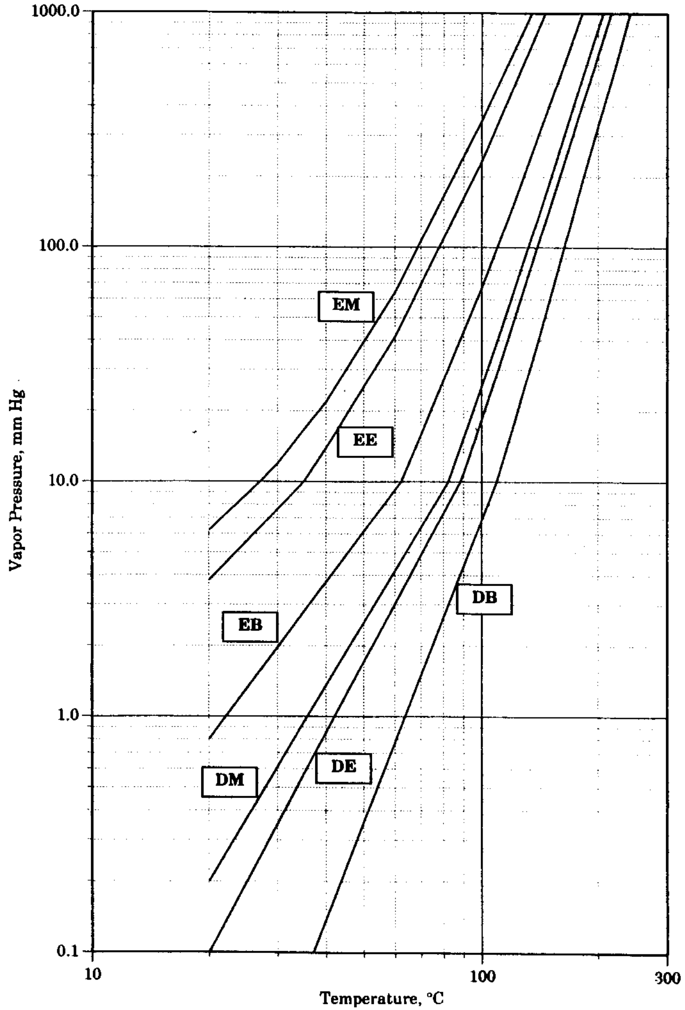
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Table 11.7: (continued)

Viscosity vs Temperature of the Glycol Ethers



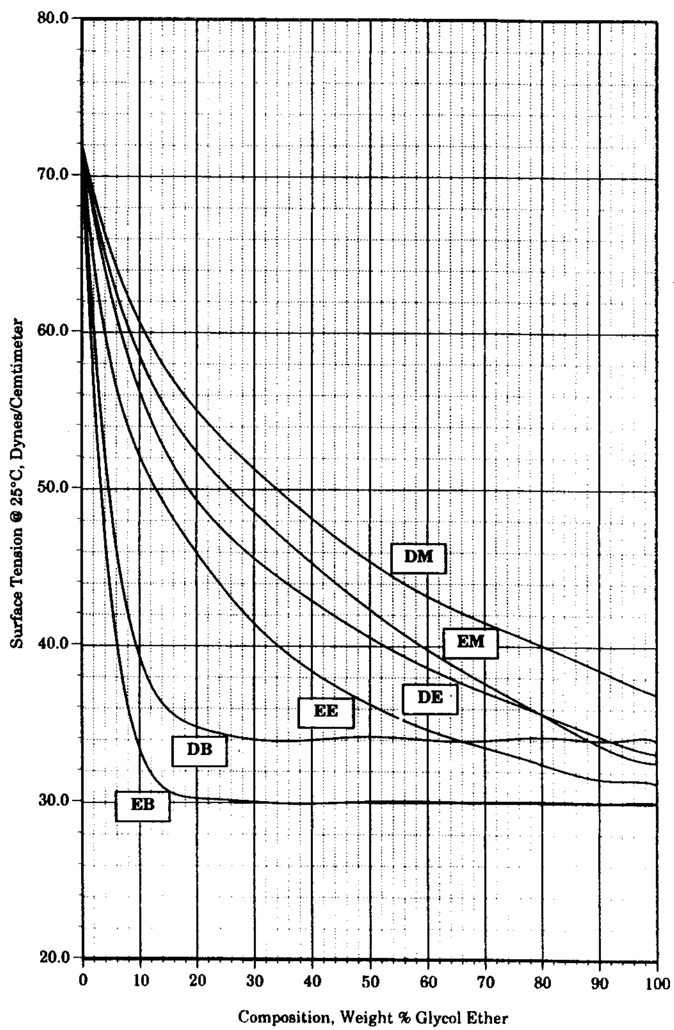
Vapor Pressure vs Temperature of the Glycol Ethers



(continued)

Table 11.7: (continued)

Surface Tension vs Composition of Aqueous Glycol Ether Solutions



Liquid/Vapor Equilibrium @ 760 mm of Aqueous Glycol Ether Solutions

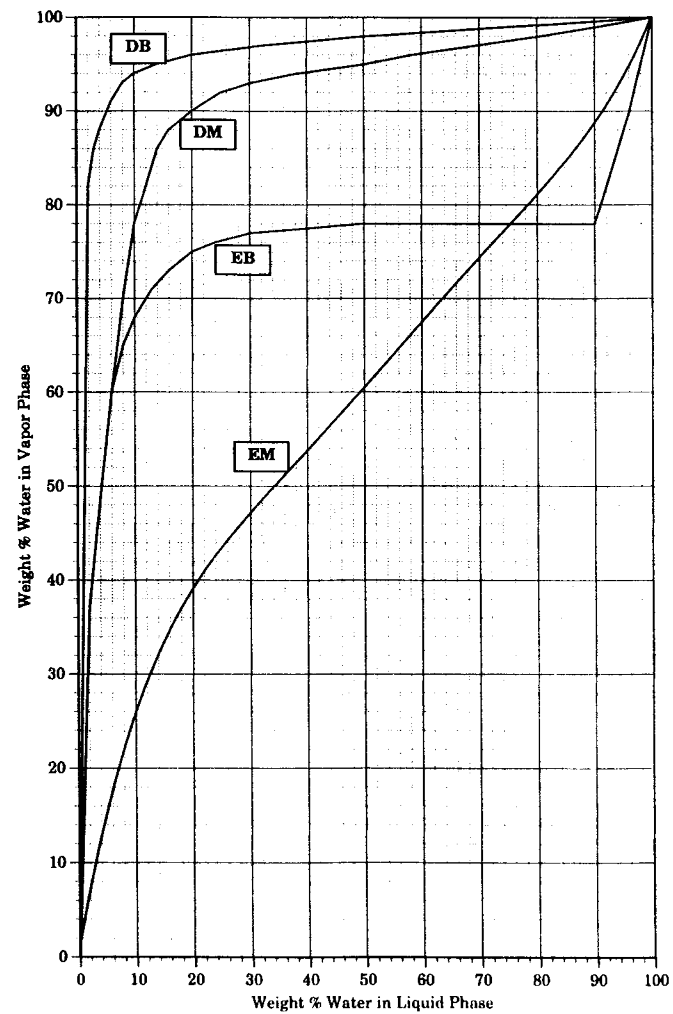


Table 11.8: Olin Chemicals Poly-Solv Propylene Glycol Ethers *(66)*

Olin produces five ethylene glycol ethers:

*Poly-Solv®** EM, ethylene glycol monomethyl ether ($CH_3OCH_2CH_2OH$)

Poly-Solv DM, diethylene glycol monomethyl ether ($CH_3OCH_2CH_2OCH_2CH_2OH$)

Poly-Solv DE, diethylene glycol monoethyl ether ($CH_3CH_2OCH_2CH_2OCH_2CH_2OH$)

Poly-Solv TM, triethylene glycol monomethyl ether $CH_3(OCH_2CH_2)_3$ OH

Poly-Solv TE, triethylene glycol monoethyl ether $CH_3CH_2(OCH_2CH_2)_3OH$

Typical Physical Properties

	EM	DM	DE	TM	TE
Boiling Point (°C)					
@ 760 mm Hg	124	194	202	249	256
@ 50 mm Hg	55	115	121	152	158
@ 10 mm Hg	27	82	87	126	130
Coefficient of Expansion					
@ 20°C	0.00095	—	—	—	—
@ 55°C	0.00099	0.00088	0.00084	—	—
Density @ 25°C (lb/gal)	8.05	8.51	8.24	8.71	8.50
Flash Point, TCC (°C)	41	87	85	—	—
(°F)	106	188	185	—	—
Flash Point, COC (°C)	—	—	—	118	124
(°F)	—	—	—	245	255
Freezing Point (°C)	-85	-85	-76	-55	-21
(°F)	-121	-121	-105	-67	-5.8
Heat of Vaporization @ 760 mm Hg (joules/g)	555.9	379.1	402.4	327.6	299.8
Molecular Weight	76.09	120.15	134.17	164.20	178.23
Refractive Index @ 20°C	1.4021	1.4263	1.4273	1.4381	1.4376
Solubility @ 20°C					
Poly-Solv in water	Complete	Complete	Complete	Complete	Complete
water in *Poly-Solv*	Complete	Complete	Complete	Complete	Complete
Specific Gravity, apparent @ 20/20°C	0.966	1.021	0.989	1.048	1.022
Specific Heat @ 20°C (joules/g-°C)	2.233	2.149	2.308	—	—
Vapor Pressure @ 20°C (mm Hg)	6.2	0.2	0.1	<0.01	<0.01
Viscosity, absolute @ 20°C (cp)	1.7	3.9	4.5	7.5	7.8

Specifications

	EM	DM	DE (regular)	DE (low gravity)	TM	TE
Water, max (% by weight)	0.01	0.1	0.2	0.1	0.1	0.1
Acidity, as acetic acid (% by weight)	0.01	0.01	0.01	0.01	0.01	0.01
Specific Gravity @ 20/20°C	0.964-0.967	1.019-1.025	1.024-1.030	0.989-0.993	1.037-1.055	1.020 1.035
Color, max (APHA)	10	15	10	10	50	50
Odor	M	M	M	M	C	C
Suspended Matter	F	F	F	F	F	F
Boiling Range (°C)						
Initial boiling point, min	123.5	191	190	198	220	225
5%, min	—	—	—	—	230	235
95%, max	—	—	200	—	—	—
Dry point, max	125.5	198	205	205	—	—

M = Mild N = Substantially none C = Characteristic F = Substantially Free

(continued)

Table 11.8: (continued)

Olin offers three propylene glycol monomethyl ethers:
*Poly-Solv®** MPM, propylene glycol monomethyl ether
$CH_3 (OC_3H_6)OH$
Poly-Solv DPM, dipropylene glycol monomethyl ether
$CH_3 (OC_3H_6)_2OH$
Poly-Solv TPM, tripropylene glycol monomethyl ether
$CH_3 (OC_3H_6)_3OH$

Specifications

	MPM	DPM	TPM
Acidity, as acetic acid, max (% by weight)	0.01	0.01	0.01
Water, max (% by weight)	0.1	0.1	—
Specific Gravity @ 20/20°C	0.922–0.925	0.953–0.957	0.964–0.976[a]
Color, max (APHA)	10	15	15
Suspended Matter	S[b]	S	S
Boiling Range @ 760 mm Hg (°C)			
Initial Boiling Point, min	119	180	236
Dry Point, max	125	196	251

[a]@ 25/25°C [b]= Substantially free

Typical Physical Properties

	MPM	DPM	TPM
Boiling Point @ 760 mm Hg (°C)	120	187	242
Flash Point[c] (°C)	32	78	107
(°F)	89	172	225
Molecular Weight	90.1	148.2	206.3
Pour Point (°C)	−97	−83	−78
Refractive Index, n_D @ 25°C	1.4036[d]	1.419	1.428
Solubility in Water	Complete	Complete	Complete
Specific Gravity @ 20/20	0.923	0.954	0.969
Vapor Pressure @ 20°C (mm Hg)	12.5	0.4	0.02
Viscosity @ 20°C (cs)	1.9	3.9	6.1

[c]Pensky Martin Closed Flask Test [d]@ 20°C

Table 11.9: Union Carbide Glycol Ethers *(19)*

	Alcohol				
Ethylene Oxide, moles	Methanol	Ethanol	Propanol	Butanol	Hexanol
1	Methyl CELLOSOLVE Solvent (Ethylene Glycol Monomethyl Ether) CAS* 109-86-4	CELLOSOLVE Solvent (Ethylene Glycol Monoethyl Ether) CAS 110-80-5	Propyl CELLOSOLVE Solvent (Ethylene Glycol Monopropyl Ether) CAS 2807-30-9	Butyl CELLOSOLVE Solvent (Ethylene Glycol Monobutyl Ether) CAS 111-76-2	Hexyl CELLOSOLVE Solvent (Ethylene Glycol Monohexyl Ether) CAS 112-25-4
2	Methyl CARBITOL Solvent (Diethylene Glycol Monomethyl Ether) CAS 111-77-3	CARBITOL Solvent (Diethylene Glycol Monoethyl Ether) CAS 111-90-0		Butyl CARBITOL Solvent (Diethylene Glycol Monobutyl Ether) CAS 112-34-5	Hexyl CARBITOL Solvent (Diethylene Glycol Monohexyl Ether) CAS 112-59-4
3	Methoxytriglycol (Triethylene Glycol Monomethyl Ether) CAS 112-35-6	Ethoxytriglycol (Triethylene Glycol Monoethyl Ether) CAS 112-50-5		Butoxytriglycol (Triethylene Glycol Monobutyl Ether) CAS 143-22-6	

*Chemical Abstract Service (CAS) Number

METHYLAL

Dimethoxymethane

Methylene Dimethyl Ether

$CH_3OCH_2OCH_3$

Methylal is a low-boiling solvent, stable in the presence of alkalis and mild acids, and to high temperatures and pressures. It differs from other ethers in that it forms only minute amounts of peroxides. It will dissolve such synthetic resins as nitrocellulose, cellulose acetate and propionate, ethyl cellulose, vinyl, "Epons" and polystyrene, and also many of the natural gums and waxes. Methylal as a latent solvent is activated by the addition of esters, ketones or alcohols. Its evaporation rate, twice that of acetone, places this ether in a class with such solvents as acetone, methyl acetate and ethyl acetate in resin formulations.

Table 11.10: Physical Properties of Methylal *(2)*

Acidity (as acetic acid), % by wt. (max.)	0.1
Aldehydes, % by wt. (max.)	0.1
Appearance	water-white
Boiling point at 760 mm. Hg, °C.	42.3
Boiling range, °C.	42.0 to 43.5
Flash point (Cleveland open cup), °F.	0
Freezing range, °C.	-104.8
Heat of combustion (Btu/lb.) at 20°C.	10.97
Refractive index (n_D at 25°C.)	1.35335
Melting point, °C.	-104.8
Methylal content, % (min.)	97
Molecular weight	76.1
Specific gravity, 20/20°C.	0.8601
Surface tension at 25°, dynes/cm.	21.1
Vapor pressure at 20°C., mm. Hg	330
Viscosity at 20°C., centipoises	0.325

ETHYLENE GLYCOLS

Table 11.11: Ethylene Glycol Monomethyl Ether *(2)*

METHYL CELLOSOLVE Solvent
POLY-SOLV EM
ARCOSOLV EM
Glycol Ether EM

$HO{-}CH_2CH_2{-}O{-}CH_3$

Ethylene glycol monomethyl ether is a colorless, limpid liquid of mild odor. It is miscible with water and with aliphatic and aromatic hydrocarbons. It is a solvent for essential oils, lignin, dammar, elemi, ester gum, kauri, mastic, rosin, sandarac, shellac, Zanzibar, nitrocellulose, cellulose acetate, alcohol-soluble dyes and many synthetic resins. Its solvency for cellulose esters is augmented when a ketone or a halogenated hydrocarbon is added. The uses for methyl "Cellosolve" are as a solvent in quick-drying varnishes and enamels, in conjunction with aliphatic, aromatic and halogenated hydrocarbons, alcohols and ketones; in solvent mixtures and thinners for lacquers and dopes; in the manufacture of synthetic resin plasticizers and as a penetrating and leveling agent in dyeing processes, especially in the dyeing of leather, animal and vegetable fibers. Other uses are as a fixative in perfumes and as a solvent in odorless nail-polish lacquers. "Dowanol EM" should not be added to nitrocellulose lacquers containing coumarone resins or ester gum because it will cause incompatibility between these substances.

(continued)

Table 11.11: (continued)

Acidity (as acetic acid) % by wt. (max.)	0.01
Boiling point at 760 mm. Hg, °C.	124.2
Color (APHA, max.)	15
Coefficient of expansion at:	
20°C.	0.00095
55°C.	0.00099
Flash point (Cleveland open cup), °F.	115
Freezing range, °C.	-85.1
Heat of vaporization (Btu/lb.)	239
Refractive index (n_D at 25°C.)	1.4021
Molecular weight	76.09
Specific gravity, 20/20°C.	0.9663
Specific heat (average) cal./°C.	0.534
Surface tension at 25°C., dynes/cm.	30.8
Solubility:	
in water at 20°C.	complete
water in at 20°C.	complete
Vapor pressure at 20°C., mm. Hg	9.7
Viscosity:	
at 25°F., centipoises	1.53
at 60°F., centipoises	0.85
Weight per gal. at 20°C., lb.	8.01

Table 11.12: Ethylene Glycol Monoethyl Ether *(2)*

CELLOSOLVE Solvent
ARCOSOLV EE
Glycol Ether EE

$HOCH_2CH_2OC_2H_5$

This colorless liquid has a mild and agreeable odor and combines a low evaporation rate with a strong solvent action. It is miscible in all proportions with acetone, benzene, carbon tetrachloride, ethyl ether, methanol and water. It has a powerful solvent action on nitrocellulose and alkyd resins and an extremely high dilution ratio with coal-tar hydrocarbons. This solvent will tolerate 4.9 times its own volume of toluene before the mixture will cease to dissolve nitracellulose, while butyl acetate will tolerate only 2.9 times its volume.

Acidity (as acetic acid), % by wt. (max.)	0.01	Specific gravity, 25/25°C.	0.9311
Appearance	water-white	Specific heat (average) cal./°C.	0.53
Boiling point at 760 mm. Hg, °C.	134.7	Surface tension at 25°C., dynes/cm.	28.2
Fire point (open cup), °F.	115	Vapor pressure at 25°C., mm. Hg	5.3
Flash point (Cleveland open cut), °F.	115	Viscosity:	
Freezing range, °C.	-59	at 25°C., centipoises	1.84
Refractive index (n_D at 20°C.)	1.4076	at 60°C., centipoises	0.94
Molecular weight	90.1	Weight per gal. at 20°C., lb.	7.72

Table 11.13: Ethylene Glycol Dimethyl Ether *(21)*

MONOGLYME

$C_2H_{10}O_2$

Molecular Weight	90.12	Surface Tension, dynes/cm 20°C	22.9
Boiling Point, °C, 760 mm Hg	85.2	Specific Heat, cal/g/°C	0.438
Freezing Point, °C	-69.0	Auto Ignition, °C	205
Specific Gravity, 20°/20°C	0.8683	Vaporization Heat, Kcal/mol	6.7
Weight per Gallon, lb 20°C	7.24	Combustion Heat, Kcal/mol	602
Vapor Pressure, mm Hg/20°C	54	Formation Heat, Kcal/mol	118
Volatility, n-Butylacetate = 100	499	Flash Point, °C, closed cup	-6
Viscosity, cp 20°C	1.1	Refractive Index, at 20°C	1.3792

Table 11.14: Ethylene Glycol Diethyl Ether *(2)*

ETHYL GLYME $C_2H_5OCH_2CH_2OC_2H_5$

Boiling point at 760 mm. Hg, °C.	121.4	Specific gravity, 20/20°C.	0.8417
Flash point (Cleveland open cup), °F.	80	Vapor pressure at 20°C., mm. Hg	9.4
Freezing range, °C.	-74	Viscosity at 20°C., centipoises	0.65
Refractive index (n_D at 25°C.)	1.3922	Weight per gal. at 20°C., lb.	7.01
Molecular weight	118.2		

Table 11.15:Ethylene Glycol Monopropyl Ether *(19)*

Propyl CELLOSOLVE Solvent
ARCOSOLV EP
Glycol Ether EP
EKTASOLVE EP

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
Propyl CELLOSOLVE Solvent	104.15	151.1	-90(c)	135	1.71

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.913	7.60	0.00095	Complete	Complete	21	26.3	32.3

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) Sets to glass below this temperature

Table 11.16: Ethylene Glycol Monobutyl Ether *(2)*

Butyl CELLOSOLVE
DOWANOL EB
EKTASOLVE E
ARCISIKV EB
Glycol Ether EB

$HOCH_2CH_2OC_4H_9$

Ethylene glycol monobutyl ether is colorless liquid, miscible in all proportions with many ketones, ethers, alcohols, aromatic paraffin and halogenated hydrocarbons. More specifically, it mixes in all proportions with acetone, benzene, carbon tetrachloride, ethyl ether, n-heptane and water. Because of its excellent solvency, low evaporation rate and high dilution ratios, it is used as a solvent in the manufacture and formulation of lacquers, enamels, inks and varnishes, employing such resins as alkyd, phenolic, nitrocellulose, maleic modified, styrene and epoxy. In lacquers butyl "Cellosolve" imparts a slow evaporation rate, strengthens blush resistance, heightens gloss, improves flow-out and helps prevent orange peel. Hot spray lacquers usually contain about 10% of "Dowanol" EB based on the solvent-diluent weight.

Acidity (as acetic acid), % by wt. (max.)	0.01	Molecular weight	118.2
Appearance	water-white	Specific gravity, 25/25°C.	0.899
Boiling point at 760 mm. Hg, °C.	170.6	Specific heat (average), cal./°C.	0.54
Fire point (open cup), °F.	165	Surface tension at 25°C., dynes/cm.	27.4
Flash point (Cleveland open cup), °F.	165	Vapor pressure at 75°C., mm. Hg	0.88
Freezing range, °C.	-40	Viscosity at 25°C., centistokes	2.83
Heat of vaporization, Btu/lb.	88.4	Weight per gal. at 20°C., lb.	7.48
Refractive index (n_D at 25°C.)	1.417		

Table 11.17: Water Solubility of Ethylene Glycol n-Butyl Ether *(23)*

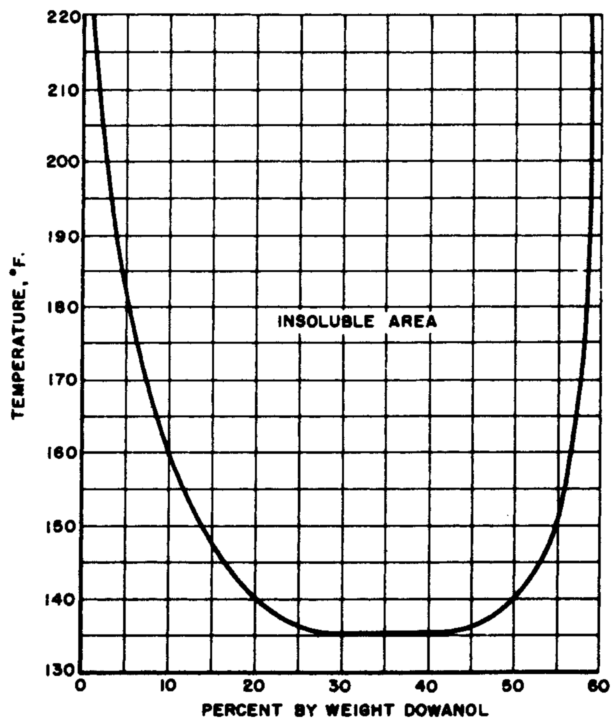
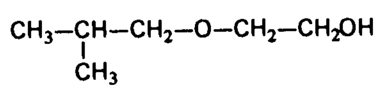


Table 11.18: Ethylene Glycol Monoisobutyl Ether *(41)*



Ethylene glycol monoisobutyl ether is a high boiling ether solvent for alkyd phenolic, malic, epoxy, alcohol-soluble butyrate, and ethyl cellulose nitrate resins.

Specifications

Color (Pt-Co Scale), ppm, max	10	Water, wt %, max	0.20
Specific Gravity, 20°/20°C	0.891-0.894	Appearance	Free from insoluble matter or haze
Boiling Range, 760 mm, °C			
Initial boiling point, min	158.0	Odor	Mild, characteristic, nonresidual
Dry point, max	162.0		
Acidity, as acetic acid, wt %, max	0.01		

(continued)

Table 11.18: (continued)

Typical Properties

Molecular Weight ($C_6H_{14}O_2$)	118.17	
Evaporation Rate (n-butyl acetate = 1)	0.1	
Weight/Vol, 20°C,		
lb/gal. (U.S.)	7.40	
kg/liter	0.89	
lb/gal. (Imperial)	8.88	
Solubility, 20°C, wt %		
In water	Complete	
Water in	Complete	
Dilution Ratio, toluene	3.1	
VM & P naphtha	1.6	
Refractive Index, 20°C	1.4168	
Vapor Pressure, 163°C, mm Hg	752	
Flash Point, Tag Closed Cup, °F (°C)	136	(58)
Tag Open Cup, °F (°C)	145	(63)
Fire Point, °F (°C)	146	(63)
Flammable Limits in Air, % by volume		
Lower	1.21	
Upper	9.4	
Autoignition Temperature (ASTM D-2155), °F (°C)	540	(282)
NFPA Classification 30:	Flammable Liquid, Class II	
ICC Labels Required	None	
Bureau of Explosives Classification	Nonhazardous Liquid	

Table 11.19: Ethylene Glycol Dibutyl Ether *(2)*

$C_4H_9OCH_2CH_2OC_4H_9$

This glycol diether is a colorless liquid. It is completely miscible with acetone, ethyl alcohol, ethyl acetate, isopropyl ether, heptane, ethylene dichloride and castor oil. Because of its being a good solvent for metallic reagents, it is particularly suitable for the Grignard type of reaction. It is also a solvent for inorganic halides and chlorosilanes, and is therefore used in silicone rubber formulations and in the extraction of aliphatic acids from dilute aqueous solutions.

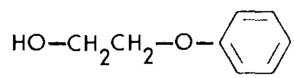
Acidity (as acetic acid), % by wt.	0.01
Boiling point, °C.	
760 mm.	203.6
50 mm.	117
10 mm.	83
$\Delta BP/\Delta P$, °C./mm. Hg	0.056
Coefficient of expansion at 55°C.	0.00105
Distillation at 760 mm., °C.	
Initial BP, min.	195
DP, max.	208
Flash point (open cut), °F.	185
Freezing point, °C.	-69.1

Table 11.19: (continued)

Heat of vaporization (Btu/lb. at 1 atm.)	118
Molecular weight	174.28
Refractive index (n_D at 20°C.)	1.4131
Solubility, % by wt. at 20°C.	
in water	0.2
water in	0.6
Specific gravity, 20/20°C.	0.8374
Δ SG/Δ T.	0.00085
Specific heat at 20°C.	0.480
lb./gal. at 60°F.	7.0
Vapor pressure, mm. Hg at 20°C.	0.09

Table 11.20: Ethylene Glycol Monophenyl Ether *(23)*

DOWANOL EPh



Ethylene glycol monophenyl ether is a colorless, high-boiling, nonhygroscopic, water-immiscible liquid with a faint rose-like odor.

Molecular Weight	**138.2**
Freezing Point, °F	**51**
Boiling Point, 760 mm Hg, °C	**245**
10 mm Hg, °C	**131.3**
Vapor Pressure @ 20°C, mm Hg	**0.03**
Specific Gravity @ 25/25°C	**1.104**
Viscosity, centistokes, 25°C	**20.5**
60°C	**4.3**
Flash Point, °F (TCC)	**260**
Specific Heat, (cal/g/°C) @ 25°C	**0.52**
Surface Tension, (dynes/cm)	
25°C	**42**
75°C	**38**
Heat of Vaporization, (cal/g) @ 760 mm Hg	**90.2**
Thermal Conductivity, K x 10^4 (cal/cm² sec °C/cm) @ 60°C	**3.86**
Pounds/Gallon @ 25°C	**9.20**
Phenol content, max. %	**0.5**

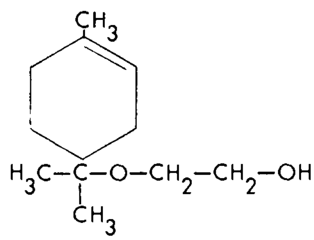
Table 11.21: Ethylene Glycol Monobenzyl Ether *(2)*

$HOCH_2CH_2OCH_2C_6H_5$

Ethylene glycol monobenzyl ether is a water-white liquid which will dissolve a large number of organic substances among which are oils, fats, greases, some vinyl resins, dewaxed damar, rosin, ester gum, etc. It is used principally as a high boiling solvent in lacquers, inks, and textile dyeing.

Acidity (as acetic acid), % by wt. (max.)	0.010
Boiling point at 760 mm. Hg, °C.	255.9
Distillation range at 760 mm. Hg, °C.	248 to 260
Flash point, °F.	265
Specific gravity at 20/20°C.	1.0670 to 1.0720
Solubility in water at 20°C., % by wt.	0.4
Solubility of water in benzyl "Cellosolve" 20°C., % by wt.	18
Vapor pressure at 20°C., mm. Hg	0.02
Weight per gal. at 20°C., lb.	8.90

Table 11.22: Terpinyl Ethylene Glycol Ether *(2)*



Terpinyl ethylene glycol ether is a light-colored liquid used in enamels, inks, paints, and varnish.

Aniline point		Below -20°C
Color (Lovibond 500 Amber Series Glasses)		3.0
Distillation range (ASTM)	5%	248.0°C
	10%	252.0°C
	30%	295.0°C
	50%	263.5°C
	70%	268.0°C
	90%	278.0°C
	95%	284.0°C
Flash point (Cleveland open cup)		284°F
Freezing point		Below -10°C
Kauri butane solvency value		Infinite
Moisture		0.05%
Refractive index at 20°C		1.4786
Specific gravity at 15.5/15.5°C		0.9813
Viscosity at 25°C (Ubbelohde)		44.6 cp

Table 11.23: Ethylene Glycol Butylphenyl Ethers *(2)*

I. - Ethylene Glycol p-sec-Butylphenyl Ether $C_{12}H_{18}O_2$

II. - Ethylene Glycol p-tert-Butylphenyl Ether $C_{12}H_{18}O_2$

	I	II
Boiling point, °F.	313 to 322/10	311 to 350/10
Flash point (Cleveland open cup), °F.	300	315
Freezing range, °F.	below -4	54
Fire point, °F.	320	325
Molecular weight	194.3	194.3
Specific gravity, 77/77°F.	1.008	1.016
Solubility (g./100 grams water)	0.1	0.1
Viscosity at 77°F., centistokes	64.6	120.7
140°F.	8.8	11.6

Table 11.24: Ethylene Glycol Monohexyl Ether *(19)*

Hexyl CELLOSOLVE Solvent
ARCOSOLV EH

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
Hexyl CELLOSOLVE Solvent	146.23	208.1	-50	179	0.051

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.889	7.40	0.00086	0.99	18.8	0.82	30.3	28.5(c)

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) 1% solution

Table 11.25: Ethylene Glycol Ethyl Hexyl Ether *(13)*

SOLV EEH
ARCOSOLV EEH
EKTASOLVE EEH

Product Name	Chemical Abstract Service Number	Evaporation Rate n-BuAc=1	Specific Gravity, @20/20°C	lb/gal @20°C	Distillation Range, °C	Viscosity cP 8% RS 1/2 sec N.C. @ 25°C	Dilution Ratio: Toluene	Dilution Ratio: Special Naphtholite (VM&P)	Flash Point, TCC,°F
Solv EEH	Mixture	0.003	0.892	7.42	224-275	Ins.	—	—	208*

*Seta Closed-Cup

Solvent Constants: Solubility Parameter	Solvent Constants: Hydrogen Bonding	Solvent Constants: Dipole Moment	Solubility @20°C: Weight % In Water	Solubility @20°C: Weight % In Water	Blush Resistance %RH @ 80°F	Electrical Resistance Megohms	Vapor Pressure mm Hg @20°C	Coefficient of Expansion (Per °C)	DOT Hazard Class	NFPA Ratings H-F-R	HMIS Ratings H-F-R	RQ (lbs.)
9.2	16.3	1.2	0.2	6.2	—	<0.3	0.08	0.0009	N-HL	0-1-0	1*-1-0	—

*may be chronic health effects (see MSDS)

Table 11.26: Diethylene Glycol *(2)*

Diglycol $HOCH_2CH_2OCH_2CH_2OH$

This hygroscopic glycol is a clear colorless, odorless and stable liquid. It is also slightly viscous, noncorrosive and nonvolatile. Because of its ether and alcohol group, diethylene glycol exhibits chemical properties characteristic of both primary alcohols and ethers. Its boiling point is considerably higher than that of ethylene glycol, and its solvent is greater. Diethylene glycol is miscible with water, ethers, lower aliphatic alcohols, aldehydes and ketones and is partially soluble in benzene, carbon tetrachloride, monobenzene, orthodichlorobenzene and toluene. It dissolves many dyes, resins, oils, nitrocellulose and many organic substances. Because of its solvent power, low volatility and hygroscopicity, it is used in textile lubricants, cutting oils, dry cleaning soap, printing inks, steam-set inks, and nongrain wood stains. In the textile industry diethylene glycol is used as a conditioning agent for wool, rayon, and cotton. As a solvent for dyes it makes a valuable assistant in dyeing and printing. The high hygroscopicity of diethylene glycol makes it an efficient softening agent for tobacco, paper, synthetic sponges, glues and casein. Diethylene glycol is especially useful in the dehydration of natural gas. A mixture of diethylene glycol and monoethanolamine will remove moisture, hydrogen sulfide and carbon dioxide from natural gas.

Acidity (as acetic acid), % by wt. (max.)	0.02
Boiling point at 760 mm. Hg, °C.	244.5
Coefficient of expansion at 20°C.	0.000635/°C.
Density (true) at 20°C., g./°C.	1.1161
Distillation range at 760 mm. Hg	
Below 320°C.	none
Below 240°C.	not over 20%
Below 250°C.	not less than 85%
Below 270°C.	not less than 95%
Electrical conductivity (reciprocal ohms)	0.586×10^{-6}
Fire point, °C.	146 (approx.)
Flash point (Cleveland open cup), °C.	143.3 (approx.)
Freezing point, °C.	-8
Heat of combustion (constant pressure) at 20°C., kcal/mol	567
Heat of formation (constant pressure), kcal/mol	148.42
Heat of vaporization at 760 mm. Hg and 244.5°C.	
Btu/lb.	270
cal./g.	150
Ignition temperature in air, °C.	351
Spontaneous ignition temperature	412.8
Molecular weight	106.12
Refractive index (n_D at 20°C.)	1.4475
Specific gravity at 20/20°C.	1.1185
Specific heat at 20°C., cal./g./°C.	0.5509
Surface tension at 25°C., dynes/cm.	48.5
Vapor pressure, mm. Hg	
20°C.	0.015
130°C.	8.0
180°C.	96.0
Viscosity (absolute), in centipoises	
15°C.	50.0
20°C.	38.0
25°C.	30.0
Water, % by wt. (max.)	0.30
Weight per gal. at 20°C., lb.	9.308

Table 11.27: Diethylene Glycol Monomethyl Ether *(2)*

DOWANOL DM
EKTASOLVE DM
Methyl CARBITOL
POLY-SOLV DM
SOLV DM
ARCOSOLV DM
Glycol Ether DM

$HOCH_2CH_2OCH_2CH_2OCH_3$

Diethylene glycol monomethyl ether is a colorless, stable hygroscopic liquid with an agreeable odor. It is completely miscible with water, ketones, alcohol, ethers, aromatic hydrocarbons and halogenated hydrocarbons. More specifically, it is miscible with acetone, benzene, carbon tetrachloride, ethyl ether, methanol and water. It is a solvent for dyes, oils, fats, waxes, many natural and synthetic resins, nitrocellulose and cellulose acetate. It is used as a high-boiling solvent in such formulations as printing inks and pastes, stamp pad inks, textile dye pastes, lacquers, and synthetic resin coatings. Its presence in lacquers eases brushability and flow-out, and minimizes lifting of undercoats.

Acidity (as acetic acid), % by wt. (max.)	0.02	Specific gravity, 25/25°C.	1.018
Appearance	water-white	Specific heat (average), cal./°C.	0.54
Boiling point at 760 mm. Hg, °C.	194.1	Surface tension at 25°C., dynes/cm.	34.8
Fire point (open cup), °F.	200	Vapor pressure at 75°C., mm. Hg	0.18
Flash point (Cleveland open cup), °F.	200	Viscosity at 20°C., centistokes	3.87
Freezing range, °C.	-50	25°C.	3.47
Heat of vaporization, Btu/lb.	163	60°C.	1.64
Refractive index (n_D at 20°C.)	1.424	Weight per gal. at 20°C., lb.	8.47
Molecular weight	120.2		

Table 11.28: Diethylene Glycol Monoethyl Ether *(2)*

CARBITOL Solvent
EKTASOLVE DE
POLY-SOLV DE Low Gravity
SOLV DE

$HOCH_2CH_2OCH_2CH_2OC_2H_5$

Diethylene glycol monoethyl ether is a colorless, stable, hygroscopic liquid of a mild, pleasant odor. It is completely miscible with water, alcohols, ethers, ketones, aromatic and aliphatic hydrocarbons, and halogenated hydrocarbons. Owing to the fact that it contains an ether-alcohol-hydrocarbon group in the molecule, it has the power to dissolve a wide variety of substances such as oils, fats, waxes, dyes, camphor and natural resins like copal, kauri, mastic, rosin, sandarac, shellac, as well as several types of synthetic resins. It is used as a solvent in synthetic resin coating compositions, and in lacquers, where high-boiling solvents are desired.

Acidity (as acetic acid), % by wt. (max.)	0.02	Molecular weight	134.2
Boiling point at 760 mm. Hg, °C.	202.0	Specific gravity, 25/25°C.	0.986
Fire point (open cup), °F.	210	Specific heat (average), cal./°C.	0.54
Flash point (Cleveland open cup), °F.	205	Surface tension at 25°C., dynes/cm.	31.8
Freezing range, °C.	-55	Vapor pressure at 75°C., mm. Hg	0.13
Heat of vaporization, Btu/lb.	84.5	Viscosity at 20°C., centistokes	3.78
Refractive index (n_D at 25°C.)	1.425	Weight per gal. at 20°C., lb.	8.20

Table 11.29: Diethylene Glycol Monoethyl Ether/Ethylene Glycol *(41)*

EKTASOLVE DE-HG

	Evaporation Rate n-BuOAc=1	Lb/ Gal @ 20°C	Color Pt-Co Max	Specific Gravity @ 20°/20°C	Acidity, as Acetic Acid Max Wt %	Boiling Range °C	Freezing Point °C	Flash Point TCC °C (°F)	Assay Min Wt %
EKTASOLVE DE-HG Solvent'* (Diethylene Glycol Monoethyl Ether/Ethylene Glycol) $[C_2H_5(OC_2H_4)_2OH][HOCH_2CH_2OH]$	<0.01	8.56	10	1.027	0.01	190-205	-70	96 (205)	—

* *High gravity solvent*

Table 11.30: Diethylene Glycol Monobutyl Ether *(2)*

ARCOSOLV DB
Glycol Ether DB

$HOCH_2CH_2OCH_2CH_2OC_4H_9$

Diethylene glycol monobutyl ether is a colorless, high-boiling liquid. It is miscible in proportions with water, alcohol (methanol), ketones (acetone), ethers (ethyl ether), aromatic hydrocarbons (benzene), paraffinic hydrocarbons (n-heptane), and halogenated hydrocarbons (carbon tetrachloride). As it is an ether-alcohol type compound it possesses solvent action for many substances such as oils, dyes, gums, and natural and synthetic resins. It is used as a high-boiling solvent in nitrocellulose lacquers and other synthetic coatings, baking lacquers, flash-dry printing inks, and dye baths.

Acidity (as acetic acid), % by wt. (max.)	0.01	Molecular weight	162.2
Appearance	water-white	Specific gravity, 25/25°C.	0.952
Boiling point at 760 mm. Hg, °C.	230	Specific heat (average), cal./°C.	0.54
Fire point (open cup), °F.	240	Surface tension at 25°C., dynes/cm.	30.0
Flash point (Cleveland open cup), °F.	230	Vapor pressure at 25°C., mm. Hg	0.023
Freezing range, °C.	-40	Viscosity at 25°C., centistokes	4.92
Heat of vaporization, Btu/lb.	74.3	Weight per gal. at 20°C., lb.	7.92
Refractive index (n_D at 25°C.)	1.430		

Table 11.31: Diethylene Glycol Monopropyl Ether *(19)*

EKTASOLV DP
SOLV DP
ARCOSOLV DP
Glycol Ether DP

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
Propyl CARBITOL Solvent	148.20	216.0	-53	210	0.02

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water in	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.969	8.06	0.00089	Complete	Complete	0.49	29.6	37.8

(a) Tag Closed Cup
(b) All solutions are percent by volume

Table 11.32: Diethylene Glycol Dimethyl Ether *(2)*

DIGLYME

$CH_3OCH_2CH_2OCH_2CH_2OCH_3$

Diethylene glycol dimethyl ether is a clear, water-white neutral liquid of faint, pleasant odor. This ether may be used as a solvent for alkali metal hydrides for use in such reactions as reduction, alkylation and condensation. It may also be used as a lacquer solvent.

Acidity (as acetic acid), % by wt. (max.)	0.015	Specific gravity, 20/20°C.	0.9451
Appearance	water-white	Surface tension at 25°C., dynes/cm.	27.0
Flash point (Cleveland open cup), °F.	168	Vapor pressure at 100°C., mm. Hg	3.0
Freezing range, °C.	-68	Viscosity at 20°C., centistokes	2.0
Refractive index (n_D at 20°C.)	1.40778	Weight per gal. at 20°C., lb.	7.87
Molecular weight	134.2		

Table 11.33: Diethylene Glycol Monoethyl Ether (Special Grade) *(23)*

CARBITOL Solvent
POLY-SOLV DE
Glycol Ether DE

Boiling point, °C	190-205
Flash point (TCC), °F	198
Evaporation rate Bu Ac = 1.0	0.01
Specific gravity 25°/25°C	1.025
Pounds per gallon 25°C	8.52
Viscosity, cs 25°C	6.9
Surface tension (dynes/cm)	33.5
Solvent constants	
Solubility parameter	11.4
Hydrogen bonding	16.6
Dipole moment (Debye)	2.05
Solubility in water ml/100 ml	∞

Table 11.34: Diethylene Glycol Monohexyl Ether *(19)*

Hexyl CARBITOL Solvent

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
Hexyl CARBITOL Solvent	190.28	259.1	-40	271	<0.01

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.935	7.78	0.00084	1.7	56.3	0.03	29.6(c)	—

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) at 20°C

Table 11.35: Diethylene Glycol Divinyl Ether *(19)*

1,5-Bis(Vinyloxy)-3-Oxapentane $CH_2{=}CHOCH_2CH_2OCH_2CH_2OCH{=}CH_2$

This vinyl ether is monomeric in character and is used as a chemical intermediate or as a crosslinking agent. Addition of isocyanic acid produces secondary diisocyanates. Divinyl ethers hydrolyze to the glycol and acetaldehyde. Chlorine or bromine add to the double bonds. Reaction with an alcohol in the presence of water produces a diacetal. Polymerization of divinyl ether of diethylene glycol with acidic catalysts produce crosslinked gels. Unsaturated polyesters, crosslinked with styrene, have been made noncorrosive to metals through use of divinyl ethers to reduce hydroxyl and acid numbers.

Boiling point, °C.:	
10 mm. Hg	81-82
12 mm. Hg	85
50 mm. Hg	115-116
Density, 29°C.	0.975
Physical form	colorless liquid
Purity	95%
Refractive index	1.4441-1.4452
Stabilizer	0.01%

Table 11.36: Diethylene Glycol Monoisobutyl Ether *(41)*

$(CH_3)_2CHCH_2OCH_2CH_2OCH_2CH_2OH$

Specifications

Color (Pt-Co Scale), ppm, maximum	10	Specific gravity, 20°/20°C	0.945-0.949
Acidity, as acetic acid, weight percent, maximum	0.01	Water, weight percent, maximum	0.10
Boiling Range, 760 millimeters, °C		Appearance	Free from insoluble matter or haze
Initial boiling point, minimum	217.0		
Dry point, maximum	225.0		

Table 11.37: Triethylene Glycol *(2)*

Triglycol

$CH_2OCH_2{\cdot}CH_2OH$
|
$CH_2OCH_2{\cdot}CH_2OH$

Triethylene glycol is a clear, colorless, viscous, stable liquid with a slightly sweetish odor. Because it has two ether and two hydroxyl groups its chemical properties are closely related to ethers and primary alcohols. It is a good solvent for gums, resins, nitrocellulose, steam-set printing inks and wood stains. With a low vapor pressure and a high boiling point, its uses and properties are similar to those of ethylene glycol and diethylene glycol. Because it is an efficient hygroscopic agent it serves as a liquid desiccant for removing water from natural gas. It is also used in air conditioning systems designed to dehumidify air.

Acidity (as acetic acid), % by wt.	0.01
Boiling point at 760 mm. Hg, °C.	287.4
Coefficient of expansion at 20°C.	0.00069
Density (true) at 20°C., g./°C.	1.1242
Fire point, °C. (approx.)	173.9
Flash point (Cleveland open cup), °C. (approx.)	330.0
Freezing point, °C.	-72
Heat of combustion (constant pressure) at 20°C., kcal/mol	850
Heat for formation (constant pressure), kcal/mol	192.9
Heat of vaporization at 760 mm. Hg and 244.5°C., cal./g.	179
Spontaneous ignition temperature, °F.	206
Surface tension at 25°C., dynes/cm.	45.2
Vapor pressure, mm. Hg:	
20°C.	0.01
101°C.	0.4
159°C.	10
202°C.	60
Water	miscible in all proportions
Weight per gal. at 20°C., lb.	7.37

Table 11.38: Triethylene Glycol Monomethyl Ether *(66)*

POLY-SOLV TM $CH_3OCH_2CH_2)_3OH$

Physical Properties

Boiling Point (°C)	
@ 760 mm Hg	249
@ 50 mm Hg	152
@ 10 mm Hg	126
Coefficient of Expansion	
@ 20°C	—
@ 55°C	—
Density @ 25°C (lb/gal)	8.71
Flash Point, TCC (°C)	—
(°F)	—
Flash Point, COC (°C)	118
(°F)	245
Freezing Point (°C)	-55
(°F)	-67
Heat of Vaporization @ 760 mm Hg (joules/g)	327.6
Molecular Weight	164.20
Refractive Index @ 20°C	1.4381
Solubility @ 20°C	
Poly-Solv in water	Complete
water in *Poly-Solv*	Complete
Specific Gravity, apparent @ 20/20°C	1.048
Specific Heat @ 20°C (joules/g-°C)	—
Vapor Pressure @ 20°C (mm Hg)	<0.01
Viscosity, absolute @ 20°C (cp)	7.5

Specifications

Water, max (% by weight)	0.1
Acidity, as acetic acid (% by weight)	0.01
Specific Gravity @ 20/20°C	1.037-1.055
Color, max (APHA)	50
Odor	C
Suspended Matter	F
Boiling Range (°C)	
Initial boiling point, min	220
5%, min	230
95%, max	—
Dry point, max	—

C = Characteristic F = Substantially Free

Table 11.39: Triethylene Glycol Monoethyl Ether *(66)*

POLY-SOLV TE $CH_3CH_2(OCH_2CH_2)_3OH$

Physical Properties

Boiling Point (°C)	
@ 760 mm Hg	256
@ 50 mm Hg	158
@ 10 mm Hg	130
Coefficient of Expansion	
@ 20°C	—
@ 55°C	—
Density @ 25°C (lb/gal)	8.50
Flash Point, TCC (°C)	—
(°F)	—
Flash Point, COC (°C)	124
(°F)	255
Freezing Point (°C)	-21
(°F)	-5.8
Heat of Vaporization @ 760 mm Hg (joules/g)	299.8
Molecular Weight	178.23
Refractive Index @ 20°C	1.4376
Solubility @ 20°C	
Poly-Solv in water	Complete
water in *Poly-Solv*	Complete
Specific Gravity, apparent @ 20/20°C	1.022
Specific Heat @ 20°C (joules/g-°C)	—
Vapor Pressure @ 20°C (mm Hg)	<0.01
Viscosity, absolute @ 20°C (cp)	7.8

Specificaltons

Water, max (% by weight)	0.1
Acidity, as acetic acid (% by weight)	0.01
Specific Gravity @ 20/20°C	1.020 1.035
Color, max (APHA)	50
Odor	C
Suspended Matter	F
Boiling Range (°C)	
Initial boiling point, min	225
5%, min	235
95%, max	—
Dry point, max	—

C = Characteristic F = Substantially Free

Table 11.40: Triethylene Glycol Dimethyl Ether *(21)*

TRIGLYME $C_8H_{18}O_4$

Molecular Weight	178.22
Boiling Point, °C 760 mm Hg	216
Freezing Point, °C	-45.0
Specific Gravity, 20°/20°C	0.9862
Weight per Gallon, lb 20°C	8.23
Vapor Pressure, mm Hg/20°C	0.02
Volatility, n-butylacetate = 100	(0.1
Viscosity, cp 20°C	3.8
Surface Tension, dynes/cm 20°C	29.4
Specific Heat, cal/g/°C	0.424
Auto Ignition, °C	195
Heat of Vaporization, K cal/mol	14.3
Heat of Combustion, K cal/mol	1191
Heat of Formation, K cal/mol	179
Flash Point, °C closed cup	111
Refractive Index n_D at 20°C	1.4224
Appearance	Clear, colorless
Odor	Mild, non-residual
Solubility at 25°C	
In water	Complete
Water in	Complete
Organics*	

*All glymes are miscible in all proportions in ethanol, acetone, benzene, diethyl ether and octane.

Table 11.41: Triethylene Glycol Monomethyl Ether/Highers *(23)*

DOWANOL TMH

DOWANOL	CHEMICAL NAME	STRUCTURAL FORMULA	Molecular Weight	Boiling Pt. °C 760 mm Hg	Flash Point °F	Evap. Rate BuAc = 1.00	Specific Gravity 25/25°C
TMH	Triethylene Glycol Methyl Ether/Highers	$CH_3O(C_2H_4O)_nH$ (n=3,4,5)	173.0 (aver.)	242.0	255[3]	<<0.01	1.054

Lb/Gal 25°C	Viscosity Centistokes 25°C	Vapor Pressure at 25°C (mm Hg)	Surface Tension (dynes/cm)	DILUTION RATIO Toluene	DILUTION RATIO Naphtha	SOLVENT CONSTANTS Solubility Parameters[1]	SOLVENT CONSTANTS Hydrogen Bonding[2]	SOLVENT CONSTANTS Dipole Moment (Debye)	SOLVENT CONSTANTS Solubility in Water ml/100 ml
8.80	7.0	<0.01	39.1	3.9	0.1	10.5	11.0	—	∞

[1] Solubility Parameters are useful as a guide in determining the ability of a solvent or solvent mixture to dissolve resins. A discussion of solubility parameters and the basis for these values are contained in an article by H.S. Burrell in the Spring 1955 issue of *Interchemical Review*.
[2] A discussion of the hydrogen bonding parameter is contained in an article by Allen A. Orr in the August 1975 issue of *Journal of Paint Technology*, Vol. 47, No. 607, pages 45-49. This particular article was the basis of the listed values of the hydrogen bonding parameter.
[3] Pensky-Martens Closed Cup (PMCC)

Table 11.42: Triethylene Glycol Monobutyl Ether/Highers *(23)*

DOWANOL TBH

DOWANOL	CHEMICAL NAME	STRUCTURAL FORMULA	Molecular Weight	Boiling Pt. °C 760 mm Hg	Flash Point °F	Evap. Rate BuAc = 1.00	Specific Gravity 25/25°C	Lb/Gal 25°C
TBH	Triethylene Glycol Butyl Ether/Highers	$C_4H_9O(C_2H_4O)_nH$ (n=3,4,5)	231.2 (aver.)	283.0	285[3]	<<0.01	0.996	8.30

Viscosity Centistokes 25°C	Vapor Pressure at 25°C (mm Hg)	Surface Tension (dynes/cm)	DILUTION RATIO Toluene	DILUTION RATIO Naphtha	SOLVENT CONSTANTS Solubility Parameters[1]	SOLVENT CONSTANTS Hydrogen Bonding[2]	SOLVENT CONSTANTS Dipole Moment (Debye)	SOLVENT CONSTANTS Solubility in Water ml/100 ml
9.2	<0.01	31.4	6.3	0.9	9.6	11.1	—	∞

[1] Solubility Parameters are useful as a guide in determining the ability of a solvent or solvent mixture to dissolve resins. A discussion of solubility parameters and the basis for these values are contained in an article by H.S. Burrell in the Spring 1955 issue of *Interchemical Review*.
[2] A discussion of the hydrogen bonding parameter is contained in an article by Allen A. Orr in the August 1975 issue of *Journal of Paint Technology*, Vol. 47, No. 607, pages 45-49. This particular article was the basis of the listed values of the hydrogen bonding parameter.
[3] Pensky-Martens Closed Cup (PMCC)

Table 11.43: Tetraethylene Glycol *(2)*

Tetraethylene glycol is a high-boiling, clear liquid of low volatility. It is completely miscible with water and a wide variety of organic solvents. For certain aliphatic hydrocarbons, it has a very slight affinity. Tetraethylene glycol is used as a coupling agent for blending water-soluble and water-insoluble compounds in such formulations as lubricants, glues, cork and textile products, etc.

Acidity (as acetic acid), % by wt. (max.)	0.01
Ash, % by wt. (max.)	0.01
Boiling point:	
760 mm. Hg, °F.	586.0
760 mm. Hg, °C.	307.8
Color, Pt-Co scale (max.)	200
Fire point, (Cleveland open cup), °F.	375
Flash point (Cleveland open cup), °F.	365
Freezing range, °F.	22
Molecular weight	194.2
Refractive index (n_D at 25°C.)	1.457
Specific gravity, 20/20°C.	1.125-7
Specific heat at 77°F. (25°C.)	0.52
Surface tension at 25°C., dynes/cm.	45
Vapor pressure at 25°C., mm. Hg	0.01
Viscosity (absolute) in centistokes:	
25°C.	39.9
60°C.	10.2
Water, % by wt.	0.20
Weight per gal. at 25°C., lb.	9.34

Table 11.44: Triethylene Glycol Dimethyl Ether *(21)*

TRIGLYME	$C_8H_{18}O_4$
Molecular Weight	222.28
Boiling Point, °C 760 mm Hg	275
Freezing Point, °C	-29.7
Specific Gravity, 20°/20°C	1.0132
Weight per Gallon, lb 20°C	8.45
Vapor Pressure, mm Hg/20°C	0.01
Volatility, n-butylacetate = 100	$<$0.1
Viscosity, cp 20°C	4.1
Surface Tension, dynes/cm 20°C	33.8
Specific Heat, cal/g/°C	0.427
Auto Ignition, °C	215
Heat of Vaporization, K cal/mol	18.7
Heat of Combustion, K cal/mol	1480
Heat of Formation, K cal/mol	217
Flash Point, °C closed cup	141
Refractive Index n_D at 20°C	1.4330
Appearance	Clear, colorless
Odor	Very mild, non-residual
Solubility at 25°C	
In water	Complete
Water in	Complete
Organics*	

*All glymes are miscible in all proportions in ethanol, acetone, benzene, diethyl ether and octane.

PROPYLENE GLYCOLS

Table 11.45: Propylene Glycol Monomethyl Ether *(2)*

ARCOSOLV PM
DOWANOL PM
POLY-SOLV MPM
Glycol Ether PM

$CH_3CHOCH_2OCH_3$

Acidity (as acetic acid), % by wt. (max.)	0.02
Appearance	water-white
Boiling point, 760 mm. Hg, °C.	120.1
Fire point (open cup), °F.	100
Flash point (Cleveland open cup), °F.	100
Freezing range, °F.	-142
Refractive index (n_D at 20°C.)	1.4021
Molecular weight	90.1
Specific gravity, 20/20°C.	0.919
Specific heat (average), cal./°C.	0.58
Surface tension at 25°C., dynes/cm.	27.7
Vapor pressure at 20°C., mm. Hg	10.9
Viscosity at 20°C., centistokes	1.75
75°C.	0.70
Weight per gal. at 20°C., lb.	7.65

Table 11.46: Propylene Glycol Monophenyl Ether *(2)*

DOWANOL PPh

Typical Physical Properties

Molecular Weight	152.2
Boiling Point, °C 760 mm Hg	242.7
Boiling Point, °C, 10 mm Hg	115.9
Freezing Point, °F	55
Specific Gravity, 25/25°C	1.063
Pounds/Gallon at 25°C	8.80
Viscosity, cs, 25°C	23.2
Flash Point, °F (TCC)	260
Specific Heat, 25°C, cal/gm/°C	0.52
Surface Tension, 25°C, dynes/cm	38.1
Refractive Index, 25°C	1.522
Solubility in Water, 25°C, g/100g	1.1
Vapor Pressure, 25°C, mm Hg	<0.1
Color, APHA	<25

Table 11.47: Propylene Glycol Monopropyl Ether *(19)*

ARCOSOLV PNP

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
Propyl PROPASOL Solvent	118.18	149.8	-80(c)	119	1.68

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.887	7.36	0.00104	Complete	Complete	22	27.0	30.4

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) Sets to glass below this temperature

Table 11.48: Propylene Glycol Monobutyl Ether *(19)*

ARCOSOLV PNB

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
Butyl PROPASOL Solvent	132.20	170.1	-80(c)	138	0.56

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.884	7.32	0.00100	5.6	14.9	8.8	27.4	32.3(d)

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) Sets to glass below this temperature
(d) 5% solution

Table 11.49: Propylene Glycol tert-Butyl Ether *(13)*

SOLV PTB
ARCOSOLV PTB
Glyrol Ether PTB

Product Name	Chemical Abstract Service Number	Evaporation Rate n-BuAc=1	Specific Gravity, @20/20°C	lb/gal @20°C	Distillation Range, °C	Viscosity cP 8% RS 1/2 sec N.C. @ 25°C	Dilution Ratio: Toluene	Dilution Ratio: Special Naphtholite (VM&P)	Flash Point, TCC,°F
Solv PTB	57018-52-7	0.25	0.870	7.27	145-155	3.8	2.3	1.2	113

Solvent Constants: Solubility Parameter	Solvent Constants: Hydrogen Bonding	Solvent Constants: Dipole Moment	Solubility @20°C: Weight % In Water	Solubility @20°C: Weight % In Water	Blush Resistance %RH @ 80°F	Electrical Resistance Megohms	Vapor Pressure mm Hg @20°C	Coefficient of Expansion (Per °C)	DOT Hazard Class	NFPA Ratings H-F-R	HMIS Ratings H-F-R	RQ (lbs.)
9.0	15.7	2.1	14.5	20.1	—	—	4.7	—	CL	2-2-0	2-2-0	—

Table 11.50: Propylene Glycol Monobutoxyethyl Ether *(19)*

Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F[(a)]	Vapor Pressure, mm Hg
176.26	230.0	-90[(c)]	197	<0.01

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution[(b)]
0.938	7.81	0.00091	∿4[(d)]	∿20[(d)]	0.13	27.6	—

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) Sets to glass below this temperature
(d) An accurate determination of the solubility of Butoxyethyl PROPASOL Solvent in water and water in Butoxyethyl PROPASOL Solvent is difficult because of the similarity of their densities and the sensitivity of the solubility to slight changes in temperature. Thus, the solubility data reported here are approximate.

Table 11.51: Propylene Glycol Isobutyl Ether and Higher Homologs *(23)*

Boiling point, °C	172	Dilution ratio	
Flash point (TCC)°F	138	Toluene	2.3
Evaporation rate BuAc = 1.0	0.09	Naphtha	1.5
Specific gravity 25°/25°C	0.883	Solvent constants	
Pounds per gallon 25°C	7.33	Solubility parameter	8.6
Viscosity, cs 25°C	4.01	Hydrogen bonding	14.8
Vapor pressure @ 25°C (mm Hg)	1.3	Dipole moment (Debye)	1.97
Surface tension (dynes/cm)	25.1	Solubility in water ml/100 ml	2.9

Table 11.52: Propylene Based Glycol Ether Blends *(23)*

DOWANOL BC-100
DOWANOL BC-200

DOWANOL	CHEMICAL NAME	STRUCTURAL FORMULA	Molecular Weight	Boiling Pt. °C 760 mm Hg	Flash Point °F	Evap. Rate BuAc = 1.00	Specific Gravity 25/25°C
BC-100	Propylene-Based Glycol Ether		—	120.0-184.0	90[3]	0.60	0.919
BC-200	Propylene-Based Glycol Ether		—	120.0-184.0	93[3]	0.25	0.924

Lb/Gal 25°C	Viscosity Centi-stokes 25°C	Vapor Pressure at 25°C (mm Hg)	Surface Tension (dynes/cm)	DILUTION RATIO		SOLVENT CONSTANTS			
				Toluene	Naphtha	Solubility Parameters[1]	Hydrogen Bonding[2]	Dipole Moment (Debye)	Solubility in Water ml/100 ml
7.68	2.39	12.5	—	5.0	0.9	10.2	14.5	1.7	∞
7.71	2.03	12.5	—	4.9	0.9	10.0	14.1	1.7	∞

[1] Solubility Parameters are useful as a guide in determining the ability of a solvent or solvent mixture to dissolve resins. A discussion of solubility parameters and the basis for these values are contained in an article by H.S. Burrell in the Spring 1955 issue of *Interchemical Review*.

[2] A discussion of the hydrogen bonding parameter is contained in an article by Allen A. Orr in the August 1975 issue of *Journal of Paint Technology*, Vol. 47, No. 607, pages 45-49. This particular article was the basis of the listed values of the hydrogen bonding parameter.

[3] Setaflash

Table 11.53: Propylene Based Glycol Ether Blend *(23)*

Boiling point, °C	179
Flash point (TCC)°F	147
Evaporation rate Bu Ac = 1.0	0.08
Specific gravity 25°/25°C	0.917
Pounds per gallon 25°C	7.62
Viscosity, cs 25°C	3.8
Vapor pressure @ 25°C (mm Hg)	0.6
Surface tension (dynes/cm)	26.4
Solvent constants	
Solubility parameters	9.0
Hydrogen bonding	14.1
Dipole moment (Debye)	1.97
Solubility in water ml/100 ml	12.0

Table 11.54: Dipropylene Glycol Monomethyl Ether *(2)*

ARCOSOLV DPM
DOWANOL DPM
POLY-SOLV DPM
Glycol Ether DM

$HOC_3H_6OC_3H_6OCH_3$

"Dowanol" DPM has a mild, pleasant odor. Because of its structure it is completely miscible with water and a wide variety of organic substances, and has the combined solubility characteristics of an alcohol, an ether and a hydrocarbon. It is used in formulations of brake fluids, lacquers, paints, varnishes, dye and ink solvents, wood stains, textile processes, dry cleaning soaps and cleaning compounds.

Acidity (as acetic acid), % by wt. (max.)	0.02	Specific gravity, 20/20°C.	0.951
Appearance	water-white	Specific heat (average), cal./°C.	0.54
Boiling point at 760 mm. Hg, °C.	188.3	Surface tension at 25°C. dynes/cm.	28.8
Fire point (open cup), °F.	185	Vapor pressure at 20°C., mm. Hg	0.4
Flash point (Cleveland open cup), °F.	185	Viscosity in centistokes: 25°C.	3.33
Freezing range, °C.	-117	75°C.	1.07
Refractive index (n_D at 20°C.)	1.419	Weight per gal. at 20°C., lb.	7.91
Molecular weight	148.2		

Table 11.55: Dipropylene Glycol Monopropyl Ether *(19)*

ARCOSOLV DPNP

Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
176.26	212.3	<-70	208	0.04

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.922	7.67	0.00093	18.0	23.0	0.64	25.8	—

(a) Tag Closed Cup
(b) All solutions are percent by volume

Table 11.56: Dipropylene Glycol Monobutyl Ether *(19)*

ARCOSOLV DPNB

Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F(a)	Vapor Pressure, mm Hg
190.28	230.6	-70(c)	230	0.05

Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution(b)
0.917	7.62	0.00092	3.0	12.0	0.40	—	—

(a) Tag Closed Cup
(b) All solutions are percent by volume
(c) Sets to glass below this temperature

Table 11.57: Dipropylene Glycol Tertiary Butyl Ether *(70)*

ARCOSOLV DPTB

ARCOSOLV DPTB is a colorless liquid with a mild odor and low volatility. It is partially water soluble and demonstrates good coupling. It also shows good solvency for coating resins. The properties of DPTB support its use in agricultural, coating, cleaning, ink, textile and adhesive products

PRODUCT IDENTIFICATION

Chemical Name ...Tertiary Butoxy Propoxy Propanol

..................Dipropylene Glycol Tertiary Butyl Ether

Chemical Family ....Propylene Glycol Ether

Chemical Formula ....$C_{10}H_{22}O_3$

(continued

Table 11.57: (continued)

TYPICAL PROPERTIES

- Density (pounds per gallon at 25°C) 7.6
- Evaporation Rate (BuAc = 100) 1.5
- Flash Point (SETA) °C (°F).......................87 (188)
- Solubility by weight in water at 20°C 12%
- Solubility Parameter (Total Hansen) 9.3
- Surface Tension (Dynes/cm) @ 25°C (77°F)......26
- Refractive Index @ 25°C (77°F) 1.42
- Viscosity (centistokes) @ 25°C (77°F)..............4.9
- Vapor Pressure @ 25°C (77°F) (mm Hg) 0.08

PRODUCT SPECIFICATIONS

Property	Specifications	Test Method
Specific Gravity @ 25°C	0.890 – 0.910	ASTM D-891
Distillation @ 760mm Hg IBP, min. DP, max.	 200°C 220°C	ASTM D-1078; E-202
Acidity, wt. % as acetic acid, max.	0.015	ASTM E-202; USP XXI
Water, wt. %, max.	0.25	ASTM E-202; E-203
Color, APHA, max.	20	ASTM E-202; D-1209

Table 11.58: Tripropylene Glycol *(2)*

Tripropylene glycol is a water-white liquid. One of its unique features is its combination of water-solubility and good solubility for many organic compounds. Because of high boiling point and low volatility it is used in the formulation of textile soaps, lubricants, cutting oils, and similar applications.

Boiling point:	
760 mm. Hg, °F.	513.0
760 mm. Hg, °C.	267.2
Fire point (Cleveland open cup), °F.	310
Flash point (Cleveland open cup), °F.	285
Freezing range	supercools
Molecular weight	192.3
Refractive index (n_D at 25°C.)	1.442
Specific heat at 77°F. (25°C.)	0.51
Surface tension at 25°C., dynes/cm.	34
Vapor pressure at 25°C., mm. Hg	0.01
Viscosity (absolute) in centistokes:	
25°C.	55.1
60°C.	9.80
Weight per gal at 25°C., lb.	8.51

Table 11.59: Tripropylene Glycol Monomethyl Ether *(2)*

ARCOSOLV TPM
DOWANOL TPM
POLY-SOLV TPM
Glycol Ether TPM

$HOC_3H_6OC_3H_6OC_3H_6OCH_3$

Tripropylene glycol monomethyl ether is a colorless liquid possessing a mild, pleasant odor. It is completely miscible with a wide variety of organic products and water. This solubility for a wide range of organic products is due to the presence of the hydroxyl, ether and alkyl group in the molecule. It is used in the manufacture of cosmetics, liquid soaps, cleaning formulation, printing and writing inks, dyeing formulations, wood stains and in lacquers, paints and varnish formulations.

Acidity (as acetic acid), % by wt. (max.)	0.02	Specific gravity, 25/25°C.	0.967
Appearance	water-white	Specific heat (average), cal./°C.	0.51
Boiling point at 760 mm. Hg, °C.	242.4	Surface tension at 25°C., dynes/cm.	30.0
Fire point (open cup), °F.	270	Vapor pressure at 75°C., mm. Hg	0.022
Flash point (Cleveland open cup), °F.	260	Viscosity in centistokes:	
Freezing range, °C.	-42	25°C.	6.16
Refractive index (n_D at 25°C.)	1.428	75°C.	1.67
Molecular weight	206.3	Weight per gal. at 20°C., lb.	8.05

Table 11.60: Aromatic Based Glycol Ether *(23)*

DALPAD A

Molecular weight	138.0
Boiling point, °C	245.0
Flash point (TCC)°F	260
Evaporation rate Bu Ac = 1.0	<0.01
Specific gravity 25°/25° C	1.104
Pounds per gallon, 25°C	9.18
Viscosity, cs, 25°C	20.5
Vapor pressure @ 25°C (mm Hg)	0.03
Surface tension (dynes/cm)	42.0
Dilution ratio	
Toluene	Insoluble
Naphtha	Insoluble
Solvent constants	
Solubility parameter	11.4
Hydrogen bonding	16.6
Dipole moment (Debye)	1.67
Solubility in water ml/100 ml	2.3

TRIGLYCOLS

Table 11.61: Methoxytriglycol *(19)*

POLY-SOLV TM
Triethylene Glycol Monomethyl Ether

Molecular weight	164.20	Freezing point, °C	-38.2
Apparent specific gravity, @ 20°/20 °C	1.053	Absolute viscosity, cp @ 20°C	7.27
ΔSpecific gravity/Δt., 10°-40°C, per °C	0.00088	Solubility @ 20°C in water	complete
Boiling point, °C		% by wt water in	complete
@ 760 mm Hg	249.0	Solubility, % by wt in	
@ 50 mm Hg	162	heptane**	1.5
@ 10 mm Hg	126	Refractive index, n_D^{20}	1.4381
Δb.p./Δp., 750 to 770 mm Hg,°C per mm Hg	0.053	Heat of vaporization, Btu/lb @ 1 atm	141
Vapor pressure at 20°C, mm Hg	<0.01	@ 300 mm Hg	150
Relative evaporation rate* (Bu Ac = 100)	<0.1	Flash point, closed cup, °F	238

*Evaporation rate of glycol ether at 20°C referenced to n-butyl acetate at 25°C.
**At 25°C the glycol ether is completely soluble in acetone, benzene, ethyl ether, methanol, and carbon tetrachloride.

Table 11.62: Ethoxytriglycol *(19)*

POLY-SOLV TE
Triethylene Glycol Monoethyl Ether

Molecular weight	178.23	Freezing point, °C	-18.7
Apparent specific gravity,		Absolute viscosity, cp	
@ 20°/20°C	1.0250	@ 20°C	7.8
ΔSpecific gravity/Δt.,		Solubility	
10°-40°C, per °C	0.00088	@ 20°C in water	complete
Boiling point, °C		% by wt water in	complete
@ 760 mm Hg	255.9	Solubility, % by wt in	
@ 50 mm Hg	167	heptane**	2
@ 10 mm Hg	130	Refractive index, n_D^{20}	1.4376
Δb.p./Δp., 750 to 770		Heat of vaporization, Btu/lb	
mm Hg,°C per mm Hg	0.055	@ 1 atm	129
Vapor pressure at 20°C,		@ 300 mm Hg	137
mm Hg	<0.01	Flash point, closed cup, °F	255
Relative evaporation rate*			
(Bu Ac = 100)	<0.1		

*Evaporation rate of glycol ether at 20°C referenced to n-butyl acetate at 25°C.
**At 25°C the glycol ether is completely soluble in acetone, benzene, ethyl ether, methanol, and carbon tetrachloride.

Table 11.63: Butoxytriglycol *(19)*

Triethylene Glycol Monobutyl Ether

Molecular weight	206.28	Freezing point, °C	-47.6
Apparent specific gravity,		Absolute viscosity, cp	
@ 20°/20°C	1.0021	@ 20°C	10.9
ΔSpecific gravity/Δt.,		Solubility	
10°-40°C, per °C	0.00082	@ 20°C in water	complete
Boiling point, °C		% by wt water in	complete
@ 760 mm Hg	(dec)	Solubility, % by wt in	
@ 50 mm Hg	188	heptane**	complete
@ 10 mm Hg	148	Refractive index, n_D^{20}	1.4394
Δb.p./Δp., 750 to 770		Heat of vaporization, Btu/lb	
mm Hg, °C per mm Hg	–	@ 1 atm	176***
Vapor pressure at 20°C,		@ 300 mm Hg	–
mm Hg	<0.01	Flash point, closed cup, °F	>250
Relative evaporation rate*			
(Bu Ac = 100)	<0.1		

*Evaporation rate of glycol ether at 20°C referenced to n-butyl acetate at 25°C.
**At 25°C the glycol ether is completely soluble in acetone, benzene, ethyl ether, methanol, and carbon tetrachloride.
***At 190°C and 50 mm Hg.

MISCELLANEOUS GLYCOL DATA

Table 11.64: ARCOSOLV Evaporation Characteristics, Resin Compatibility and Other Data *(70)*

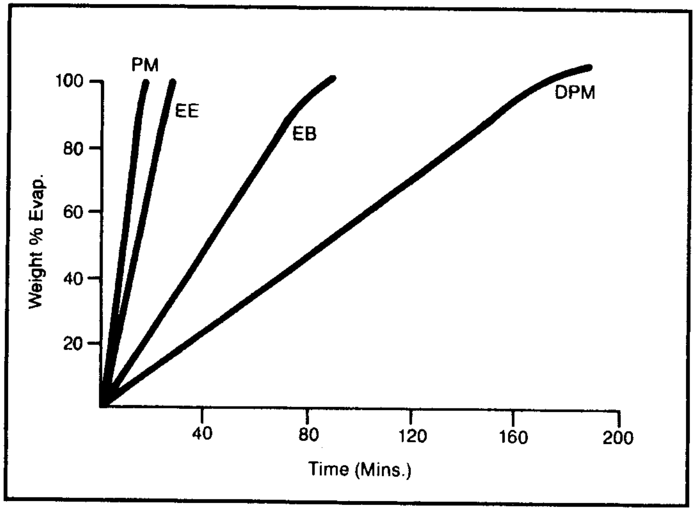
Relative Solvent Evaporation Rates

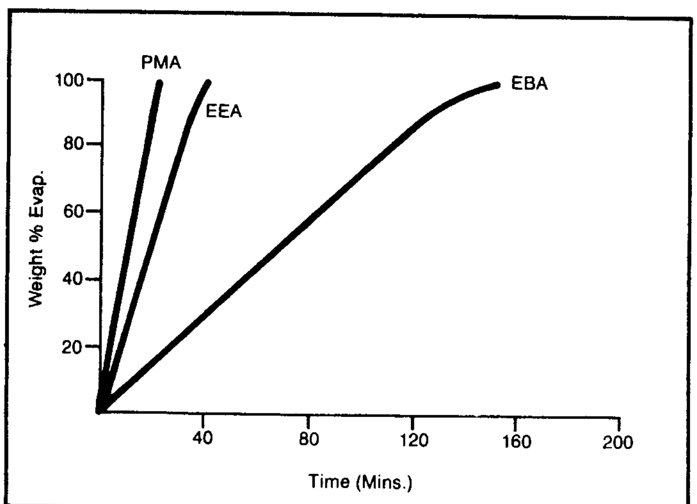
Fast Evaporating (>300)	
Acetone	559
Ethyl Acetate	391
Methyl Ethyl Ketone	379
Medium Evaporating (80-300)	
Methanol	207
Isopropyl Alcohol	144
Butyl Acetate	100
Slow Evaporating (<80)	
PM	66
EM	47
EE	32
EB	6
DPM	2
PMA	34
EEA	20

(continued)

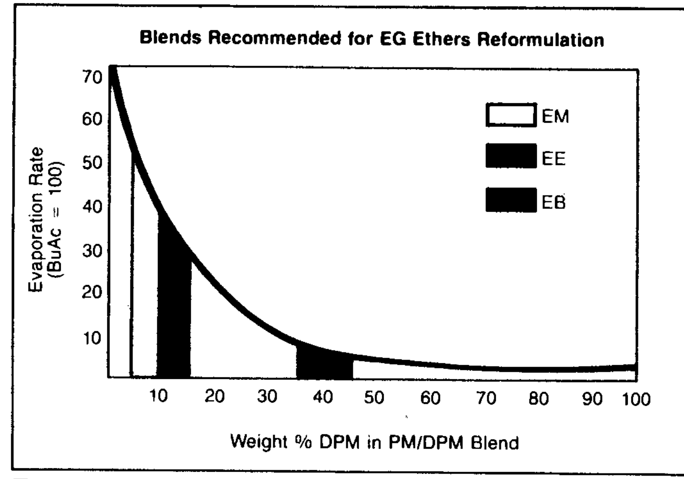
Table 11.64: (continued)

Evaporation Curves—Neat Solvents

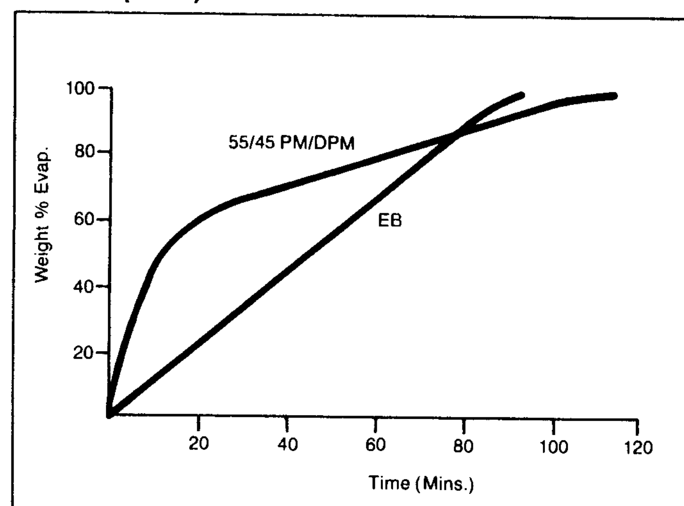




Evaporation Rates for PM/DPM Blends



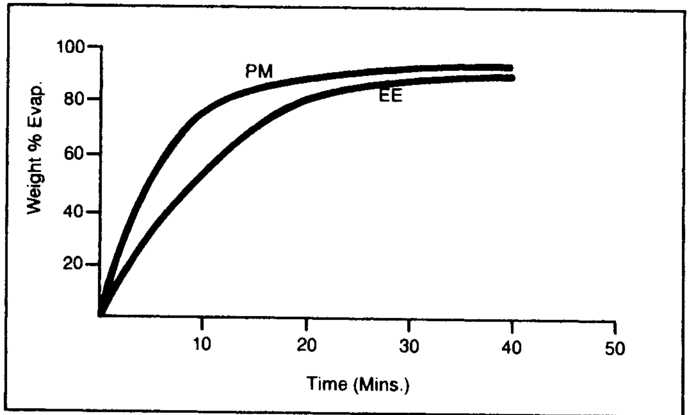
Evaporation Curves—55/45 PM/DPM Blend and EB (25°C)



(continued)

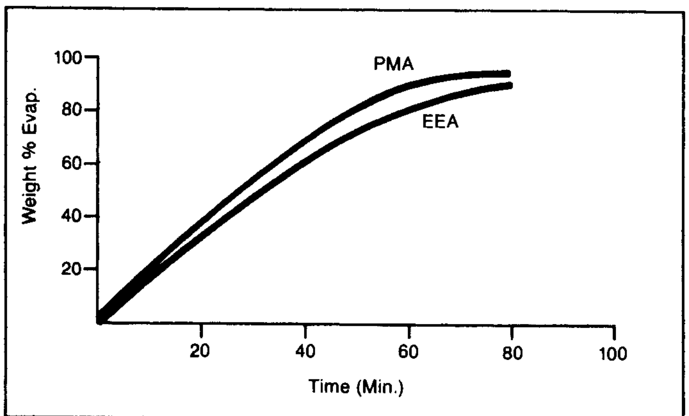
Table 11.64: (continued)

Evaporation Curves from 60% Araldite® 6010* Epoxy Resin



* Ciba-Geigy Corp.

Evaporation Curves from 10% RS 1/2 Sec. Nitrocellulose* Resin

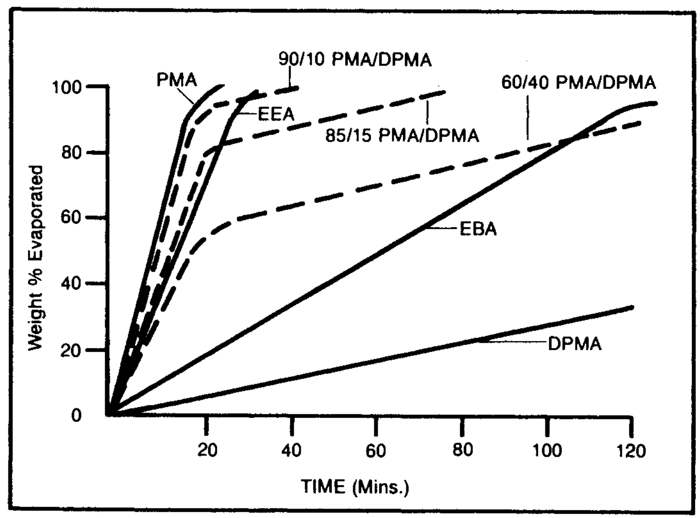


*Hercules, Inc.

Evaporation Times of Glycol Ether Acetates

Glycol Ether Acetate	Minutes to 90% Evaporation
PMA	17
EEA	28
EBA	115
DPM	315
DEA	500
DBA	2700

Evaporation Curves—Glycol Ether Acetates and PM Acetate/DPM Acetate Blends (25°C)



(continued)

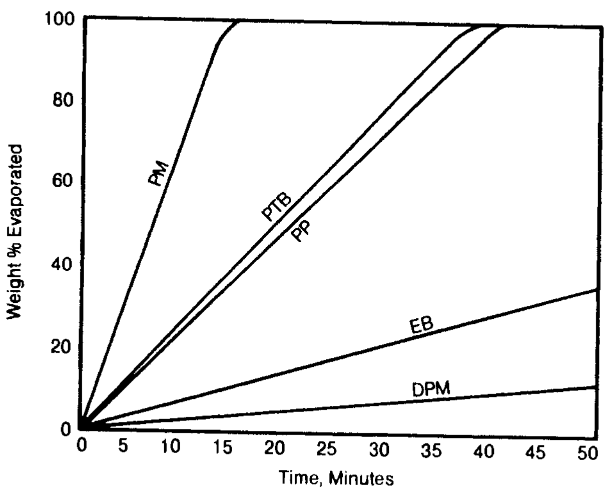
Table 11.64: (continued)

Glycol Ether Azeotropes with Water

Glycol Ether	b.p. of pure glycol ether, C at 760mm Hg	b.p. of azeotrope, C at 760mm Hg	Composition of Azeotrope Glycol Ether, Wt. %	Water, Wt. %
EE	136	99	29	71
EP*	150	99	27	73
EB	171	99	21	79
PM	121	98	50	50
PTB	151	95	21	79
PP	149	97	41	59
PB	170	99	28	72

*Ethylene Glycol Propyl Ether

ARCOSOLV PTB Ether and other Glycol Ethers Evaporation Curves—Neat Solvents



Compatibility of ARCOSOLV® PM Solvent with Various Film Formers

Resin Tradename[1]	Compatibility[2] Wt.% ARCOSOLV PM/Resin 10/90 Soln	10/90 Film	50/50 Soln	50/50 Film	90/10 Soln	90/10 Film
Acrylic						
Acryloid AT-51	C	C	C	C	C	VH
Elvacite 2041	NS[3]	—	NS[4]	—	NS	—
Acryloid OL-42	C	C	C	C	C	C
Alkyd (Solvent Reducible)						
Beckosol 12-006	C	C	C	C	C	C
Duraplex 12-808	C	C	C	C	C	C
Cargill 5836	C	C	C	C	C	C
Alkyd (Vinyl Toluene/Oil)						
Keltrol 1001	C	C	C	C	NS	—
Alkyd (Water Reducible)						
Kelsol 3902	C	C	C	C	C	C
Kelsol 3921	C	C	C	C	C	C
Cellulose Acetate Butyrate						
CAB 381-05	C[3]	C[3]	C[4]	C[4]	C	C
Chlorinated Rubber						
Parlon S-20	NS[4]	—	—	—	NS	NS
Epoxy						
Araldite 6010	C	C	C	C	C	C
Araldite 7071	C[5]	C[5]	C	C	C	C
Ethylene Vinyl Acetate						
Elvax 40	—	—	NS	—	NS	—
Melamine Formaldehyde						
Uformite 27-806	C	C	C	C	C	C
Cymel 303	C	C	C	C	C	C
Nitrocellulose						
Cellofilm No. 101175	C	C	C	C	C	C
Polyamide						
Hardener HZ 815X70	C	C	C	C	C	C
Hardener HZ 815	C	C	C	C	C	C
Hardener HZ 840	C	C	C	H	C	C
Urea Formaldehyde						
Beetle 227-8	C	C	C	C	C	C
Beckamine 21-511	C	C	C	C	C	C
Urethane						
Spenkel F-78-50	C	C	C	C	C	H
Spenkel F-48-50	C	C	C	C	C	SH
Spenkel F-77-60	C	C	C	C	C	C
Vinyl Chloride/Acetate						
Vinylite VYNS	NS[3]	—	NS[4]	—	NS	—
Vinylite VAGH	NS[3]	—	NS[4]	—	NS	—
Vinylite VYHH	NS[3]	—	NS[4]	—	NS	—

C - Clear
H - Hazy
V - Very
S - Slight
NS - Not Soluble
— - Not Tested

1. *See Table for supplier listing by tradename.*
2. *All testing carried out under ambient conditions. Resins were used as received from manufacturer. Criterion for solubility in solutions was two hours shaking. Sample size was 200 g. Films were applied at 3 mils thickness on glass and air dried 48 hours.*
3. *20% Resin/80% ARCOSOLV PM solvent.*
4. *5% Resin/95% ARCOSOLV PM solvent.*
5. *75% Resin/25% ARCOSOLV PM solvent.*

(continued)

Table 11.64: (continued)

Resin Suppliers

Resin Tradename	Supplier	% Solids	Solvents
Acrylic			
Acryloid AT-51	Rohm and Haas	50	Xylene/n-Butanol
Elvacite 2041	DuPont	100	—
Acryloid OL-42	Rohm and Haas	80	EEA
Alkyd (Solvent Reducible)			
Beckosol 12-006	Reichhold	50	Xylene/VM&P Naphtha
Duraplex 12-808	Reichhold	60	Xylene
Cargill 5836	Cargill	70	EEA
Alkyd (Vinyl Toluene/Oil)			
	Spencer Kellogg	60	Mineral Spirits
le)			
	Spencer Kellogg	75	EB
	Spencer Kellogg	75	Propylene Glycol Propyl Ether
Cellulose Acetate Butyrate			
	Eastman	100	—
	Hercules	100	—
Epoxy			
Araldite 6010	Ciba-Geigy	100	—
Araldite 7071	Ciba-Geigy	100	—
Ethylene Vinyl Acetate			
	DuPont	100	—
	Reichhold	80	i-Propanol/i-Butanol
	American Cyanamid	100	—
Cellofilm No. 101175 ½ Sec. Solution	Cellofilm	40	Methylisobutyl Ketone/ Toluene/Butyl Acetate/n-Butanol
Polyamide			
	Ciba-Geigy	70	Xylene
	Ciba-Geigy	100	—
	Ciba-Geigy	100	—
Urea Formaldehyde			
Beetle 227-8	American Cyanamid	52	Xylene/n-Butanol
Beckamine 21-511	Reichhold	60	n-Butanol/Ethanol
Urethane			
	Spencer Kellogg	50	Mineral Spirits
	Spencer Kellogg	50	Mineral Spirits
	Spencer Kellogg	60	Mineral Spirits
Vinyl Chloride/Acetate			
Vinylite VYNS	Union Carbide	100	—
Vinylite VAGH	Union Carbide	100	—
Vinylite VYHH	Union Carbide	100	—

Viscosities of PM with Various Resins

Resin	Final % Sols.	Viscosity, cps at 25°C PM	EE	EB
Acrylic[1]	**30**	390	430	650
Epoxy[2]	**60**	690	780	1010
Nitrocellulose[3]	**10**	**250**	**280**	**370**
Polyester[4] (bake)	**60**	**290**	**270**	**390**
Alkyd[5] (wat. red.)	**60**	**410**	**410**	**580**

1. Acryloid® B-72 (Rohm and Haas)
2. Epon® 1001 (Shell Chemical Co.)
3. RS ½ Sec. Nitrocellulose (Hercules, Inc.)
4. Aroplat® 6025-A1-80 (Spencer Kellogg, Division of Textron, Inc.)
5. Cargill 7451 (Cargill, Inc.)

Viscosities of PM/DPM Blends with Various Resins

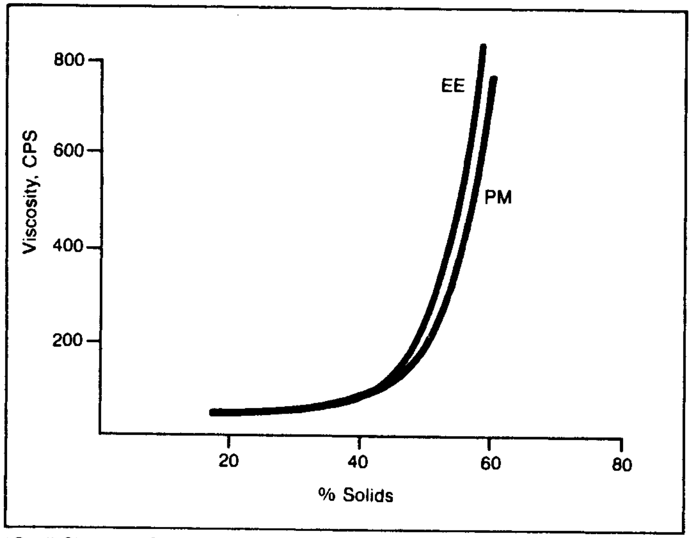
Resin	Final % Sols.	Viscosity, cps at 25°C PM	DPM	EE	EB	PM/DPM 95/5	PM/DPM 90/10	PM/DPM 65/35
Acrylic[1]	30	390	910	430	650	415	440	540
Alkyd[2]	50	460	840	490	645	480	490	600
Epoxy[3]	80	170	400	170	230	180	190	235

1. Acryloid® B-72 (Rohm and Haas)
2. Cargill 7433 (Cargill, Inc.)
3. ARALDITE® 6010 (Ciba-Geigy Corporation)

(continued)

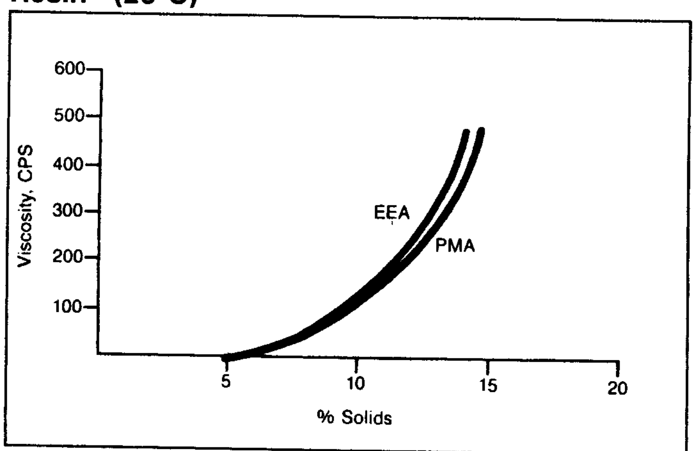
Table 11.64: (continued)

Viscosity Reduction
EPON® 1001
Epoxy Resin* (25°C)



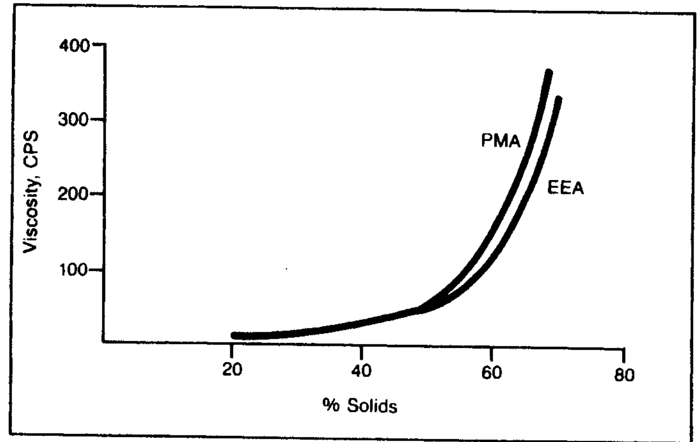
*Shell Chemical Company

Viscosity Reduction
RS ½ Sec. Nitrocellulose
Resin* (25°C)



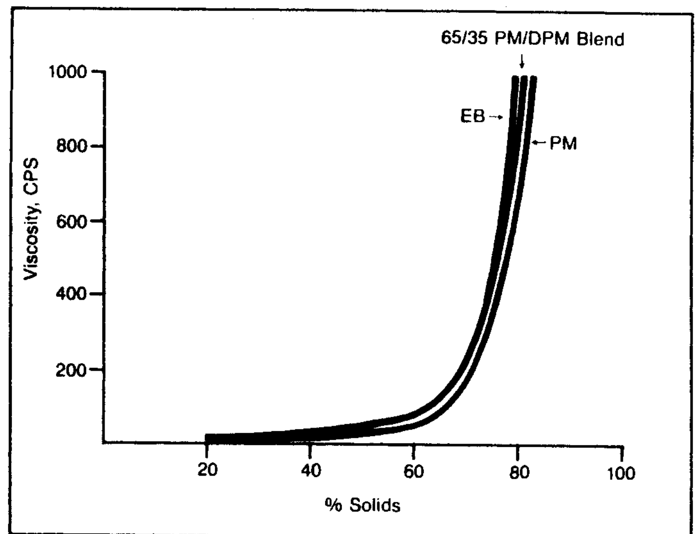
*Hercules, Inc.

Viscosity Reduction
Aroplaz® 6230
Alkyd Resin* (25°C)



*Spencer Kellogg Division, Textron, Inc.

Viscosity Reduction
CARGILL 5710
Alkyd Resin* (25°C)

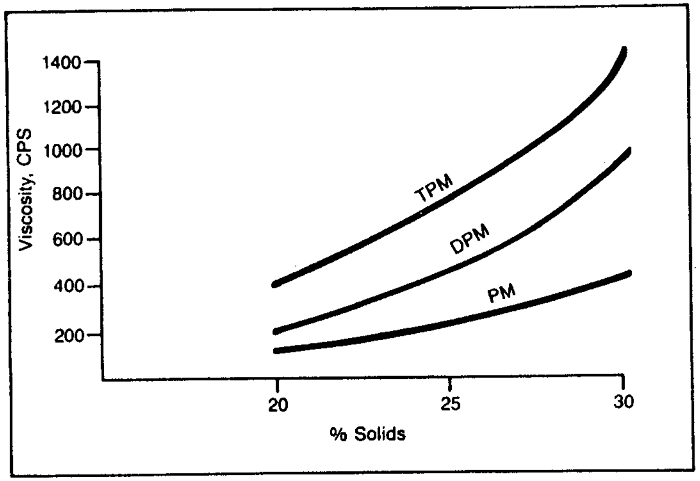


*Cargill, Inc.

(continued)

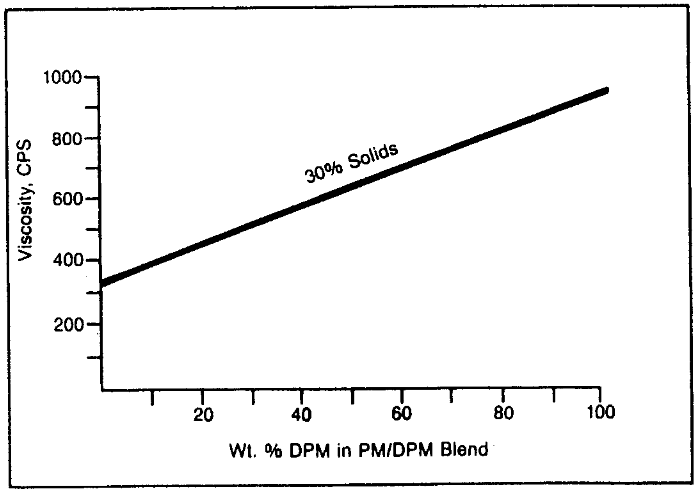
Table 11.64: (continued)

Viscosity Reduction
Acryloid® B-72 Acrylic Resin*



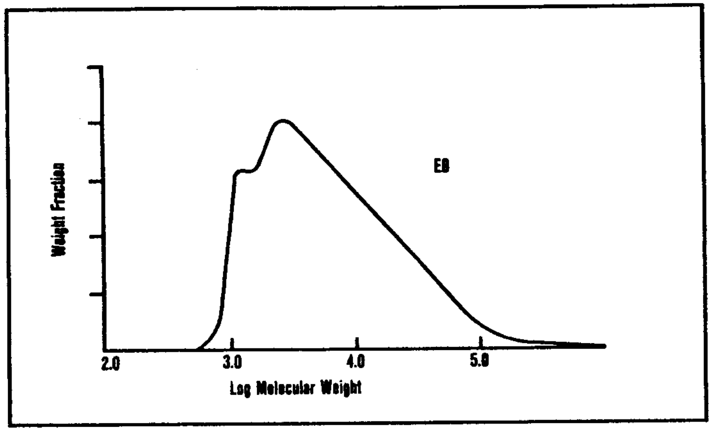
*Rohm and Haas Co.

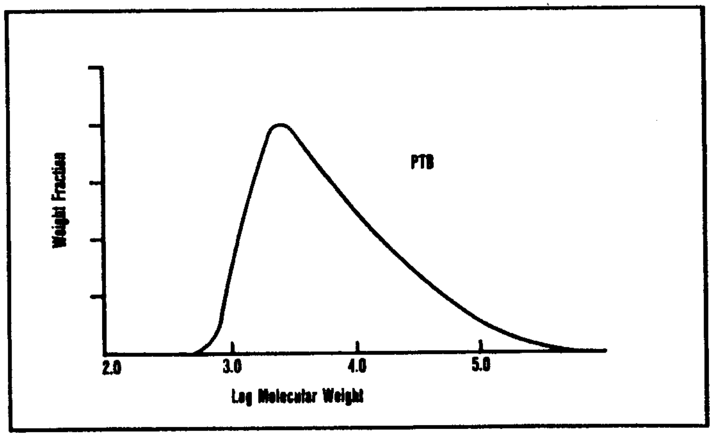
Viscosity of Acryloid® B-72 Acrylic Resin* in PM/DPM Blends



*Rohm and Haas Co.

Alkyd Resin Stability
125°F, Four Weeks





(continued)

Table 11.64: (continued)

Performance[1] of ARCOSOLV* DPMA in a Vinyl Acrylic Interior Wall Paint (6.8 Wt. % Coalescent)

Coalescent	None	Texanol[2]	EBA	ARCOSOLV* DPM Acetate
Viscosity (KU)	87	88	87	87
Film Appearance (Sealed/Unsealed)				
77°F	10/10	10/10	10/10	10/10
40°F	10/10	10/10	10/10	10/10
Sheen—85°F (Sealed/Unsealed)				
77°F	17/15	18/14	15/14	16/12
40°F	12/10	19/15	16/14	16/14
Hiding (Sealed Area)				
77°F	96.9	97.1	96.6	97.0
40°F	95.5	96.1	95.5	96.3
Reflectance—% (Sealed Area)				
77°F				
Unstained	91.9	92.1	91.8	92.1
Stained	86.6	86.2	85.5	85.5
40°F				
Unstained	89.7	92.5	92.2	92.2
Stained	72.1	84.8	84.2	85.0

1. *ASTM Standardized Scoring Scheme*

Score	Performance	Effect
10	Perfect	None
9	Excellent	Trace
8	Very Good	Very Slight
6	Good	Slight
4	Fair	Moderate
2	Poor	Considerable
1	Very Poor	Severe
0	No Value	Complete Failure

2. *Trademark of Eastman Chemical Products, Inc.*

Improved Whiteness in Coatings using ARCOSOLV* Glycol Ethers and Acetates

Formulation	Solvent	Whiteness Index (4B-3G Reflectance)
Epoxy Baking Enamel	PM	80.2
	EE	78.4
Epoxy Maintenance Enamel	PM	77.6
	EE	75.8
High Solids Alkyd Enamel	PM	78.5
	EB	76.2
Polyester Appliance Enamel	PMA	79.7
	EEA	78.5

Whiteness Study—Reduced Amount of Titanium Dioxide White Epoxy Baking Enamel

	PM		EE	
TiO_2 Reduction, %	–	10	–	10
Whiteness Index	85.5	85.5	84.6	83.5
Opacity	94.5	94.1	94.0	92.0

Effect of Grinding Method on Whiteness White Epoxy Baking Enamel

	High Speed Dispersion		Sand Mill	
	PM	EE	PM	EE
Viscosity (CPS)	25,000	19,000	400	1200
Grind (Hegman No.)	7	7	8+	8+
Whiteness Index	86.3	83.0	86.9	83.1
Opacity	95.4	93.6	96.0	93.8
Whiteness Index	86.4	84.5	86.3	83.3
At 99.9+ % Opacity				

Hard Surface Cleaner Evaluation Selected Glycol Ethers

Glycol Ether	Performance: Shell "Janitor in a Drum"[1] Type	ARCO All Purpose
EB	79	80
ARCOSOLV PM	78	79
ARCOSOLV DPM	79	81
ARCOSOLV TPM	78	80

1. *Trademark of Texize Chemical Company*

(continued)

Table 11.64: (continued)

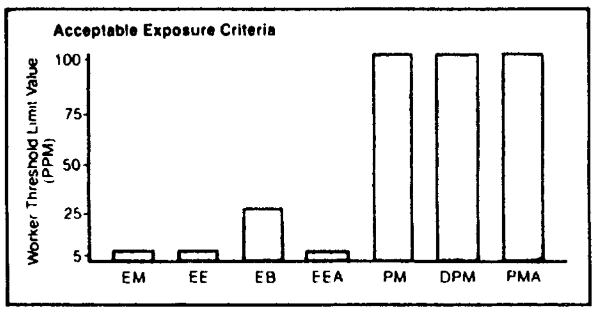
Evaluation of ARCOSOLV Glycol Ethers in Household Cleaners

Cleaner	Performance Rating: Ethylene Glycol Butyl Ether	Performance Rating: ARCOSOLV PM/DPM 60/40 Blend
All Purpose Hard Surface Type[1]	91	98
Spray-On Metal Cleaner	Excellent	Excellent

Formulations: All Purpose Hard Surface Type		Spray-On Metal Cleaner	
Glycol Ether	5.0 Wt.%	Glycol Ether	20.0 Wt.%
Trisodium Phosphate	2.0	Makon® 10 Surfactant[3]	20.0
Sodium Metasilicate (5 Hydrate)	2.0	Kerosene	60.0
Sodium EDTA (Anhydrous)	2.0		
Tergitol® 15-S-9 Surfactant[2]	7.0		
Na Xylene Sulfonate (40%)	1.0		
Water	81.0		

1. *Evaluated in accordance with Federal Specification P-D-220D. Soil described in Method 6701T of Federal Test Method Standard 436.*
2. *Union Carbide Corporation.*
3. *Stepan Chemical Company.*

ARCOSOLV Acceptable Exposure Criteria



TLV's of 5 ppm for EM, EE and their acetate derivatives established by the American Conference of Governmental Industrial Hygienists (ACGIH) in May 1984. Several glycol ether producers are recommending 2–5 ppm on EM and 5 ppm on EE and EEA. The ANPR could result in more severe restrictions. There is no standard established by ACGIH for PMA. Based on a comparison with PM TLV, a comfort level of 100 ppm would be recommended for PMA. For detailed information as for our toxicity bulletin or product MSDS

ARCOSOLV Comparative Aquatic Technology

LC-50s (mg/L)							
GLYCOL ETHER	DAPHNIA MAGNA	BLUE GILL	FATHEAD MINNOW	RAINBOW TROUT	GUPPY	GOLDFISH	LAMPREY EEL
PM	23,000	N/D	20,800	N/D	N/D	N/D	N/D
PMA	408	N/D	161	N/D	N/D	N/D	>5,000
PE	N/D	N/D	N/D	N/D	N/D	N/D	>5,000
PNP	3,600	N/D	3,420	N/D	N/D	N/D	N/D
PNB	>1,000	N/D	N/D	N/D	560	N/D	>5,000
PTB	>1,000	>1,000	N/D	>1,000	N/D	N/D	N/D
PPh	370	N/D	280	N/D	N/D	N/D	N/D
DPM	1,919	N/D	>10,000	N/D	N/D	N/D	N/D
DPNB	>1,000	N/D	N/D	N/D	841	N/D	N/D
TPM	>10,000	N/D	11,600	N/D	N/D	N/D	N/D
TPNB	>1,000	N/D	N/D	N/D	564	N/D	N/D
EM	>10,000	>10,000	N/D	16,000	17,400	>5,000	N/D
EE	N/D	>10,000	N/D	N/D	16,400	>5,000	N/D
EB	835	1,490	2,137	N/D	983	1,700	N/D

N/D = No Data Located

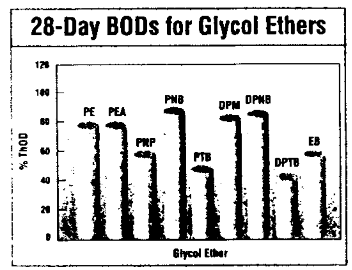
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Biodegradation of selected propylene glycol ethers after 28 days incubation. Test performed in the same laboratory, with pre-acclimated inoculum, using the same dose (3.75 mg/l).

(continued)

Table 11.64: (continued)

TOXICOLOGICAL ENDPOINTS TABLE		Birth Defects		Embryo/Fetal Toxicity		Testicular Toxicity		Blood Damage		Thymic Atrophy	
		NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
PM	Inhalation (ppm)	3,000	NLF	1,000	3,000	3,000	NLF	3,000	NLF	3,000	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF
	Oral (mg/kg/d)	3,000	NLF	370	740	5,000	NLF	3,000	NLF	3,000	NLF
***beta*-PM**	Inhalation (ppm)	145	225	145	225	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	NNF	1,800	N/D	N/D
PMA	Inhalation (ppm)	3,000	NLF	3,000	NLF	3,000	NLF	3,000	NLF	3,000	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
***beta*-PMA**	Inhalation (ppm)	145	560	560	NLF	560	2,800	2800	NLF	2800	NLF
	Dermal (mg/kg/d)	2,000	NLF	2,000	NLF	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
PE	Inhalation (ppm)	2,000	NLF	2,000	NLF	2,000	NLF	300	2,000	2,000	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	~1,800	NLF	~1,800	NLF	~1,800	NLF
PEA	Inhalation (ppm)	N/D	N/D	N/D	N/D	1,176	NLF	1,176	NLF	1,176	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
PNP	Inhalation (ppm)	1,524	NLF	755	NLF	600	NLF	600	NLF	600	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
PNB	Inhalation (ppm)	N/D	N/D	N/D	N/D	700	NLF	700	NLF	700	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	1,140	NLF	1,140	NLF	1,140	NLF
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF
PTB	Inhalation (ppm)	990	NLF	990	NLF	709	NLF	709	NLF	709	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
PPh	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
DPM	Inhalation (ppm)	300	NLF	300	NLF	300	NLF	300	NLF	300	NLF
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	~5,000	NLF	~5,000	NLF	~5,000	NLF
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF

(continued)

Table 11.64: (continued)

TOXICOLOGICAL ENDPOINTS TABLE *(continued)*		Birth Defects		Embryo/Fetal Toxicity		Testicular Toxicity		Blood Damage		Thymic Atrophy	
		NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
DPE	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF
DPNP	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
DPNB	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	910	NLF	910	NLF	910	NLF	910	NLF	910	NLF
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF
DPTB	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
TPM	Inhalation (ppm)	119	NLF	119	NLF	120	NLF	120	NLF	120	NFL
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	10,000*	NLF	~10,000*	NLF	~10,000*	NLF
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
TPE	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
TPNB	Inhalation (ppm)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Dermal (mg/kg/d)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	N/D	N/D	N/D	N/D	1,000	NLF	1,000	NLF	1,000	NLF
EM	Inhalation (ppm)	10	50	10	50	30	100	30	100	30	100
	Dermal (mg/kg/d)	NNF	250	NNF	250	NNF	650	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	31	250	NNF	31	50	100	10	50	NNF	100
EE	Inhalation (ppm)	50	175	10	50	100	400	100	370	N/D	N/D
	Dermal (mg/kg/d)	NNF	~250	NNF	~250	N/D	N/D	N/D	N/D	N/D	N/D
	Oral (mg/kg/d)	NNF	200	NNF	1,000	150	300	93	185	N/D	N/D
EB	Inhalation (ppm)	200	NLF	25	50	494	NLF	25	77	494	NLF
	Dermal (mg/kg/d)	1,176	NLF	1,176	NLF	360	NLF	150	180	360	NLF
	Oral (mg/kg/d)	1,180	NLF	30	100	885	NLF	80	90	885	NLF

N/D = No Data • NNF = No NOAEL Found (Lowest dose tested caused the effect) • NLF = No LOAEL Found (Highest dose tested did not cause the effect)
• Kidney toxicity was reported at lower doses.

Table 11.65: DOWANOL Miscibility, Solubility, Evaporation Rates, Vapor Pressure, Density, Surface Tension and Other Data *(23)*

Liquids Miscible With DOWANOL Glycol Ethers

Acetaldehyde	Diacetone Alcohol[1]	Furfural	Phenyl Acetate
Acetic Acid (Glacial)	Dibutoxy Ethyl Phthalate[1]	Isopropanol	Phosphoric Acid (Conc.)
Acetic Anhydride	Dibutyl Phthalate	Isopropylbenzene (Cumene)	Pine Oil
Acetone	Dibutyl Sebacate[1]	Isopropyl Chloride[1]	Piperidine[1]
Acetylene Tetrabromide	o-Dichlorobenzene	Lactic Acid 85%	Polyethylene Glycol 400[1]
Acrylonitrile[1]	Dichloroethyl Ether	Methanol	Polyethylene Glycol 600[1]
Allyl Alcohol[1]	Dichloroisopropyl Ether[1]	Methyl Cyclohexanol[1]	Polypropylene Glycol 400[1]
Amyl Alcohol	Diethanolamine	Methyl Ethyl Ketone	Polypropylene Glycol 750[1]
tert-Amyl Alcohol[1]	Didecyl Phthalate[1]	Methyl Isobutyl Ketone	Polypropylene Glycol 1200[1]
Amyl Acetate	Diethyl Ether	Methyl Salicylate	n-Propanol
Aniline	Diethylene Glycol	Methylene Bromide	Propylene Dichloride
Benzaldehyde	Di-2-Ethylhexyl Phthalate[1]	Methylene Chlorobromide[1]	Propylene Glycol
Benzene	Di-2-Ethylhexyl Sebacate[1]	Methylene Chloride	Pyridine[1]
Benzyl Alcohol	Diisoctyl Phthalate[1]	Monochlorobenzene	Ricinoleic Acid[1]
n-Butyl Acetate	Dimethoxy Ethyl Phthalate[1]	Monoethanolamine	Styrene N-99[1]
n-Butyl Alcohol	p-Dioxane	Monoisopropanolamine	Styrene Oxide[1]
n-Butyl Lactate[1]	Diphenyl Oxide	Morpholine	Tetrachloroethane
Butyl Oleate[1]	Dipropylene Glycol	Nitrobenzene	Tetrahydrofurfuryl Alcohol
n-Butyraldehyde	Ethanol (95%)	Nitroethane[1]	Toluene
Carbon Bisulfide	Ethyl Acetate	Nitromethane	Trichloroethylene
Carbon Tetrachloride	Ethyl Benzene[1]	Octyl Alcohol	1,1,1-Trichloroethane
Castor Oil	Ethyl Bromide[1]	Oleic Acid	Tricresyl Phosphate[1]
Chloroform	Ethylene Chlorohydrin[1]	Paraldehyde	Triethanolamine
CHLOROTHENE* solvent	Ethylene Dibromide	Pentachlorodiphenyl Oxide[1]	Triethylene Glycol
Cyclohexanol	Ethylene Dichloride	Perchloroethylene	Trimethylene Chlorobromide[1]
Cyclohexanone[1]	Ethylene Glycol	Phenethyl Acetate[1]	Tripropylene Glycol
Cyclohexene	Ethylidene Dichloride[1]	Phenethyl Alcohol[1]	Tall Oil
Dehydrated Castor Oil 9-11 Acids[1]	Ethyl Lactate[1]	Phenetole[1]	Xylene

[1] The solubility of these products has not been determined for DOWANOL EPh, DALPAD A, and DOWANOL PPh
*Trademark of The Dow Chemical Company

Solubility Limits of Various Liquids in DOWANOL Glycol Ethers[1] (ml/100 ml)

COMPOUND	PM	DPM	TPM	PPh	EB	DB	TBH	DM	TMH	EPh
n-Butyl stearate	∞	∞	∞	∞	∞	∞	—	8	—	∞
Cottonseed oil	∞	∞	∞	∞	∞	∞	—	Ins.	—	6
Cyclohexane	∞	∞	∞	∞	∞	∞	—	64	—	33
Diamylnaphthalene	∞	∞	∞	—	∞	∞	—	∞	—	—
Di-2-ethylhexyl adipate	∞	∞	∞	—	∞	∞	—	∞	—	—
Fish oil	∞	∞	∞	—	∞	∞	—	1.5	—	—
Formaldehyde (40%)	∞	∞	∞	21	∞	∞	∞	∞	∞	∞
Formamide (37-38% stabilized)	∞	∞	∞	12	∞	∞	—	∞	—	∞
Gasoline	∞	∞	∞	∞	∞	∞	∞	22	∞	10
n-Heptane	∞	∞	∞	46	∞	∞	∞	19	23	8
Hexane	∞	∞	∞	70	∞	∞	93	21	25	12
Hydrochloric acid (conc.)	∞	∞	∞	5.2	∞	∞	∞	∞	∞	∞
Kerosene	∞	∞	∞	∞	∞	∞	—	3	—	0.5
Linseed oil (boiled)	∞[2]	∞	∞	∞	∞	∞	∞	<0.4	Ins.	∞
Lemon oil	∞	∞	∞	—	∞	∞	—	∞	—	—
Methyl cyclohexane	∞	∞	∞	—	∞	∞	—	46	—	—
Oiticica oil	∞	∞	∞	—	∞	∞	—	∞[3]	—	—
Olive oil	∞	∞	∞	∞	∞	∞	∞	Ins.	Ins.	∞
Peanut oil	∞	∞	∞	—	∞	∞	∞	Ins.	Ins.	—
Safflower oil	∞	∞	∞	—	∞	∞	∞	Ins.	Ins.	—
Soybean oil	∞	∞	∞	—	∞	∞	∞	Ins.	Ins.	—
Turpentine	∞	∞	∞	—	∞	∞	∞	55	28	—
Tung oil	∞[4]	∞[5]	∞	—	∞	∞	∞	Ins.	Ins.	—
Water	∞	∞	∞	1.1	∞	∞	∞	∞	∞	2.3

[1] Solubility data refer only to room temperature. For many DOWANOL glycol ether products, solubility is very dependent on temperature.
[2] Above 48 ml solute; smaller quantities give hazy solutions.
[3] Above 80 ml solute; smaller quantities give hazy solutions.
[4] Above 86 ml solute; smaller quantities give hazy solutions.
[5] Above 20 ml solute; smaller quantities give hazy solutions.

(continued)

Table 11.65: (continued)

Solubility of Various Soaps in DOWANOL Glycol Ethers[1] (g/100 g)

COMPOUND	PM	DPM	TPM	PPh	EB	DB	DM	EPh
Monoethanolamine laurate	19	4	3	7	37	21	15	3
Monoethanolamine oleate	>100	>100	>100	>100	>100	>100	>100	>100
Monoethanolamine stearate	3	1	<1	2	2	<1	<1	<1
Diethanolamine laurate	>100	97	28	>100	>100	>100	>100	>100
Diethanolamine oleate	>100	>100	>100	>100	>100	>100	>100	>100
Diethanolamine stearate	28	7	4	66	26	14	7	38
Triethanolamine laurate	>100	22	18	68	90	58	67	80
Triethanolamine oleate	>100	>100	>100	>100	>100	>100	>100	>100
Triethanolamine stearate	15	6	5	21	13	5	<1	27
Monoisopropanolamine laurate	>100	37	15	>100	>100	>100	>100	>100
Monoisopropanolamine oleate	>100	>100	>100	>100	>100	>100	>100	>100
Monoisopropanolamine stearate	3	2	1	11	5	4	<1	<1
Monoethanolamine tall oil	>100	>100	>100	>100	>100	>100	>100	>100
Triethanolamine tall oil	>100	>100	>100	>100	>100	>100	>100	>100
Mixed Isopropanolamine tall oil	>100	>100	>100	>100	>100	>100	>100	>100
Potassium oleate	>100	>100	>100	—	>100	>100	>100	—
Sodium oleate	<1	<1	<1	—	1	1	1	—

[1] The solubilities of the various soaps in the DOWANOL glycol ether products were determined by the following method. The various substances were added by weight to 25g of DOWANOL glycol ether; the samples were than shaken mechanically for 15 hours.
All solubility studies were carried out at room temperature. Solubility was determined on basis of a true solution.
Solubility in all cases is reported as grams dissolved in 100g of DOWANOL glycol ether.

Resin Solubility†

COMPOUND	PM	DPM	TPM	PMA	DPMA	PPh	EB	DB	DM	EPh
Acrylic Acryloid[1] B-66	●	●	●	●	●	●	●	●	●	●
Acryloid B-72	●	●	●	●	●	●	●	●	●	●
Acryloid B-82	●	●	●	●	●	●	●	●	●	●
Elvacite[2] 2010	●	★	■	●	★	★	○	○	●	★
Epoxy D.E.R.* 651	●	●	●	●	●	●	●	●	●	●
D.E.R. 657	●	●	●	●	●	●	●	●	●	●
Melamine Cymel[3] 303	●	●	●	●	●	●	●	●	●	●
Isocyanate Desmodur[4] N100	●[7]	●[7]	●[7]	●	●	●[7]	●[7]	●[7]	●[7]	●[7]
Nitrocellulose R.S ½ sec	●	●	●	●	●	■	●	●	●	■
R.S. ¼ sec	●	●	●	●	●	★	●	●	●	■
Alkyd Cargill 5710	●	●	●	●	●	●	●	●	●	●
Polyester Cargill 5781	●	●	●	●	●	●	●	●	●	●
Chempol[5] 11-2339	●	●	●	●	●	●	●	●	●	●
Cellulosic CAP-482-0.5	●	★	■	●	●	●	■	■	●	●
CAB-381-2	●	■	■	●	●	●	○	○	●	●
Phenoxy UCAR[6] PKHC	●	●	●	●	●	●	●	●	●	●
Vinyl UCAR VYHH	○	○	○	●	■	■	○	○	■	★

† METHOD: Solubility observations were made after 0.5 g resin and 4.5 ml solvent were agitated for 24 hours.

* Trademark of The Dow Chemical Company
[1] Acryloid Trademark of Rohm & Haas Company
[2] Elvacite Trademark of E.I. DuPont de Nemours & Company
[3] Cymel Trademark of American Cyanamid Company
[4] Desmodur Trademark of Farbenfabriken Bayer AG
[5] Chempol Trademark of Freeman Chemical Corporation
[6] UCAR Trademark of Union Carbide Corporation
[7] Soluble, but not recommended for use

● Soluble
★ Partially soluble, some undissolved gel particles
■ Partially soluble, many undissolved gel particles
○ Insoluble

(continued)

Table 11.65: (continued)

Coupling Abilities of DOWANOL Glycol Ethers and Alcohols

Composition of Titrant, Volume %									
PM	**DPM**	**TPM**	**EB**	**DB**	**DM**	**sec-butanol**	**isobutanol**	**n-butanol**	**ml to couple[1]**
			100						32.8
			75			25			34.2
			50			50			37.9
50								50	41.0
	25					75			42.1
				100					42.5
			25			75			48.8
25								75	51.0
	50						50		58.3
						100			60.9
	25						75		61.8
	50					50			63.9
75								25	64.0
		100							67.0
								100	71.0
	75						25		78.8
100									80.0
	75					25			82.1
	100								95.8
							100		104.6
					100				230.0

[1] Milliliters of product required to titrate 10 ml of mineral spirits and 10 ml of water to a clear homogeneous solution at 25°C.

Evaporation Rates of DOWANOL Products

DOWANOL	(BuAc = 1.00)[1]	DOWANOL	(BuAc = 1.00)
PM	0.71	BC-300	0.21
DPM	0.02	EB	0.08
TPM	<0.01	DB	0.003
PMA	0.34	TBH	<<0.01
DPMA	<0.01	DM	0.02
PPh	<0.01	TMH	<<0.01
BC-100	0.60	EPh	<0.01
BC-200	0.25	DALPAD A	<0.01

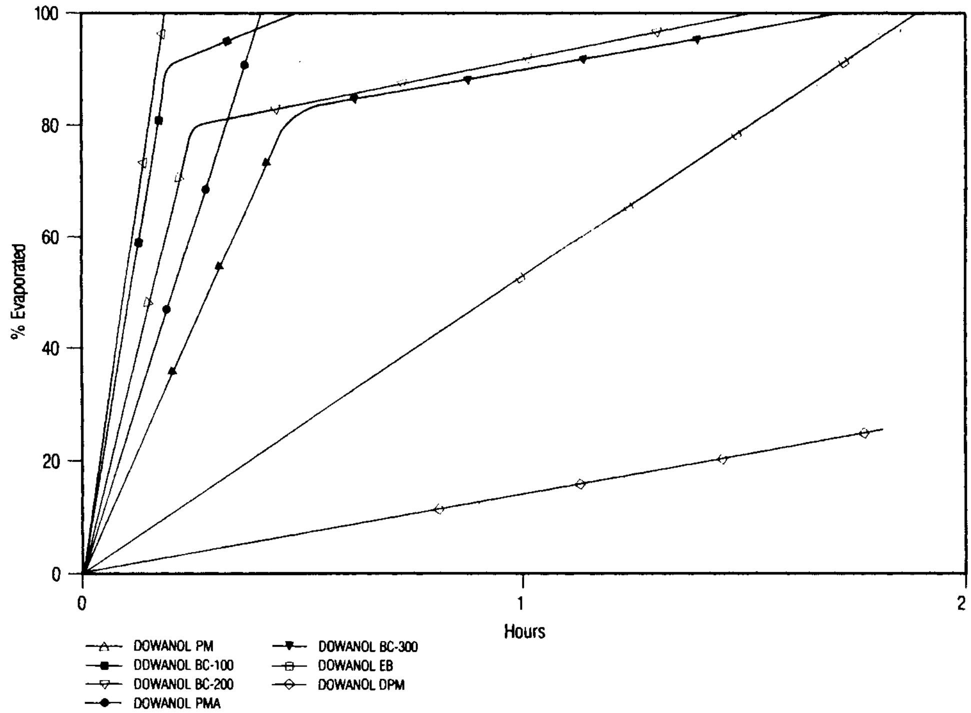
[1] Chemists use the evaporation rate of butyl acetate as the standard for determining evaporation rates of solvents. Butyl acetate has an arbitrary value of 1.00. All solvents evaporating faster than butyl acetate have a number higher than 1.00. Those evaporating more slowly have evaporation rates lower than 1.00. All glycol ethers evaporate more slowly than butyl acetate.

(continued)

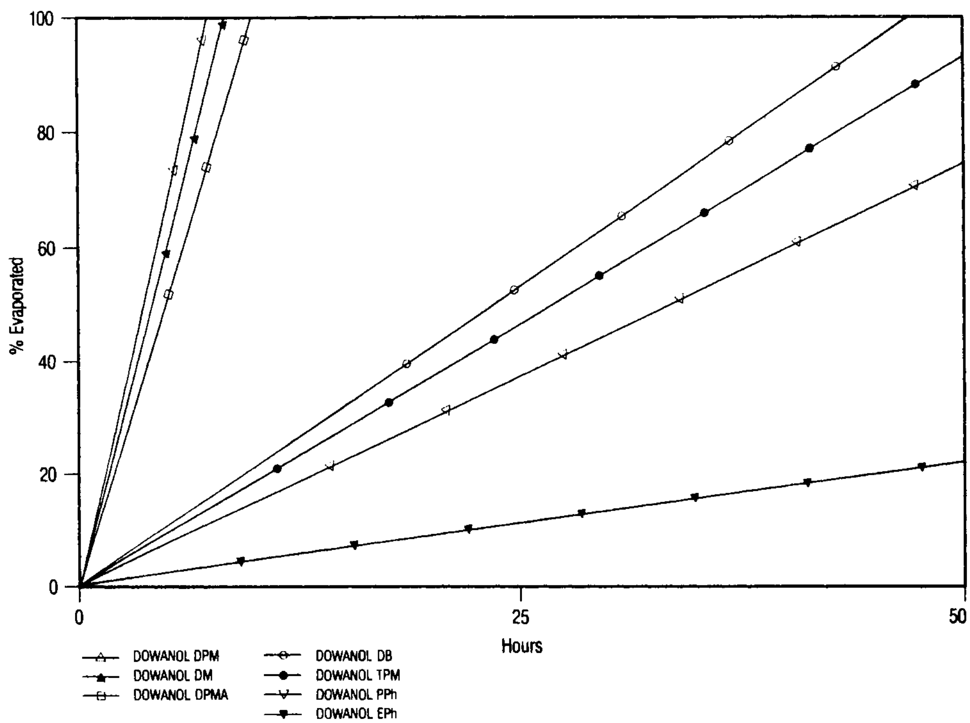
Table 11.65: (continued)

Evaporation Rates of DOWANOL Products

High Evaporation Rate



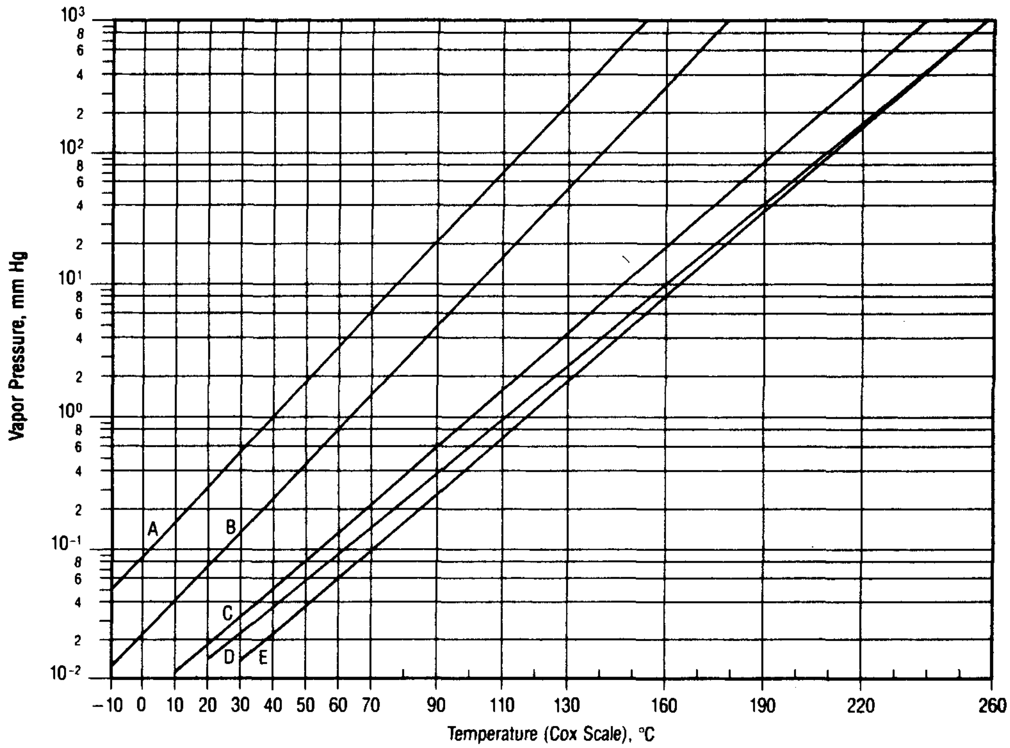
Low Evaporation Rate



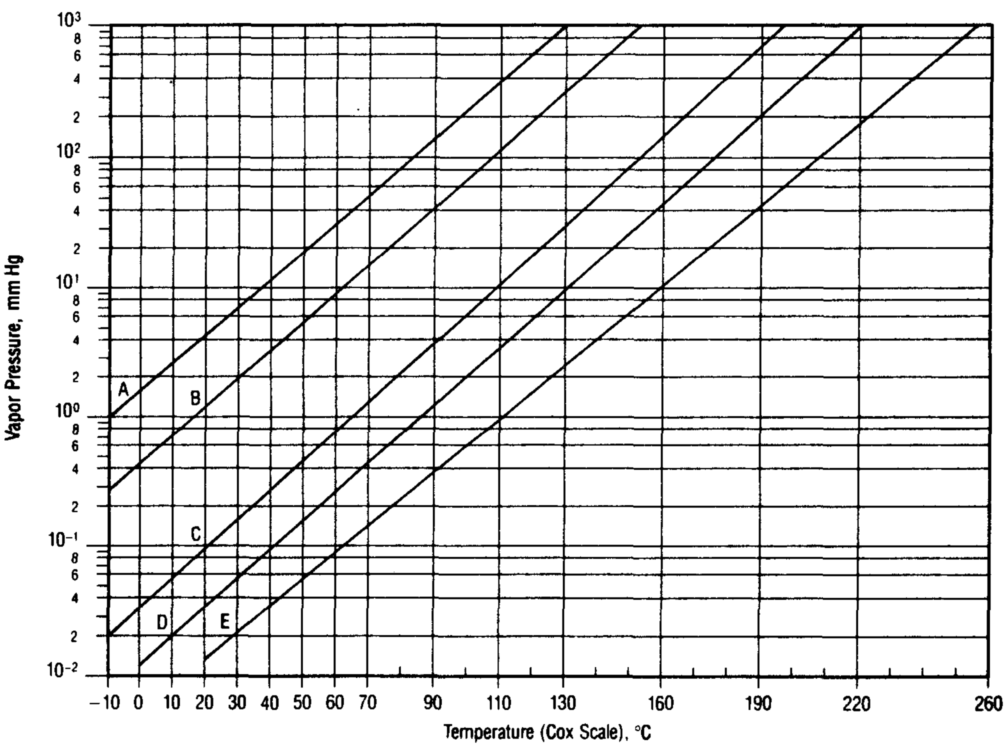
(continued)

Table 11.65: (continued)

Vapor Pressures of DOWANOL Products



A = DOWANOL EB B = DOWANOL DM C = DOWANOL DB D = DOWANOL PPh E = DOWANOL EPh

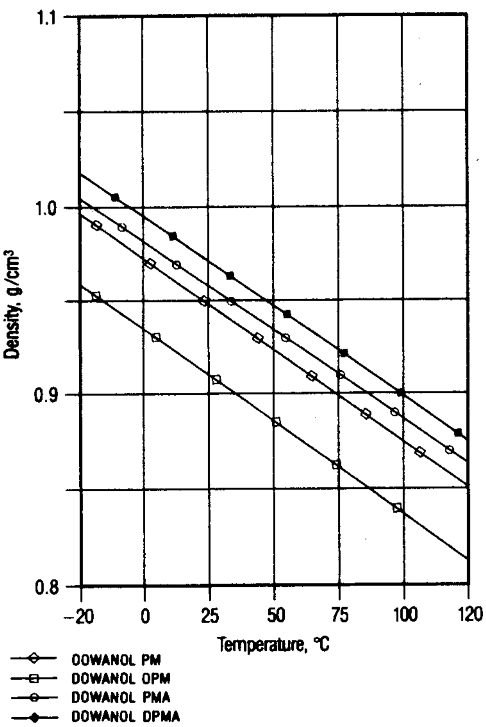


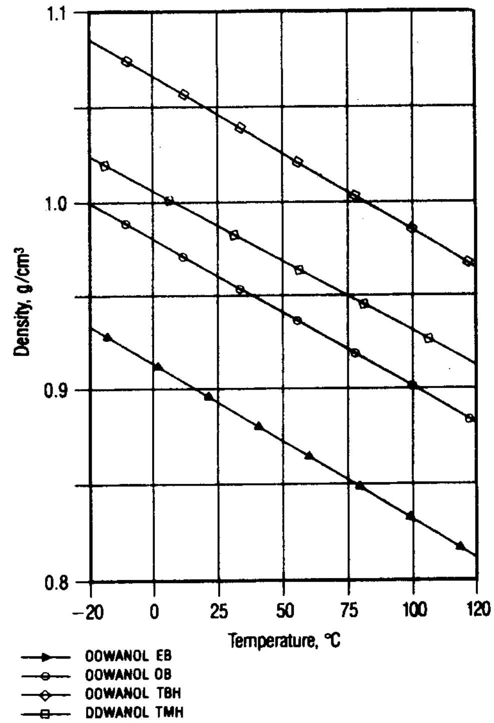
A = DOWANOL PM B = DOWANOL PMA C = DOWANOL DPM D = DOWANOL DPMA E = DOWANOL TPM

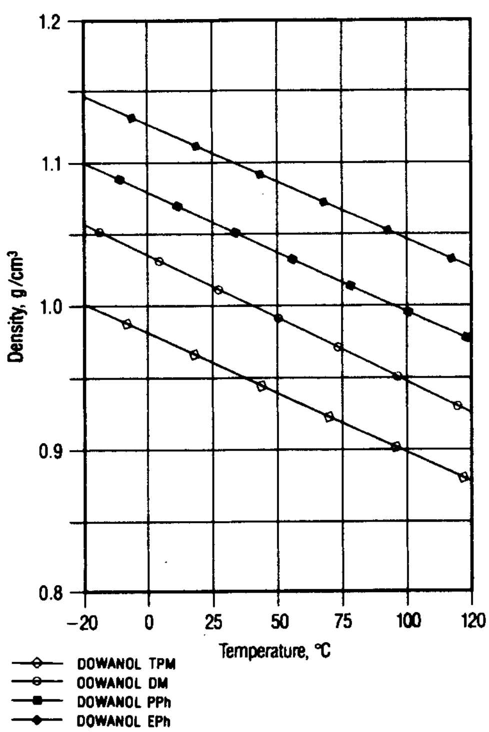
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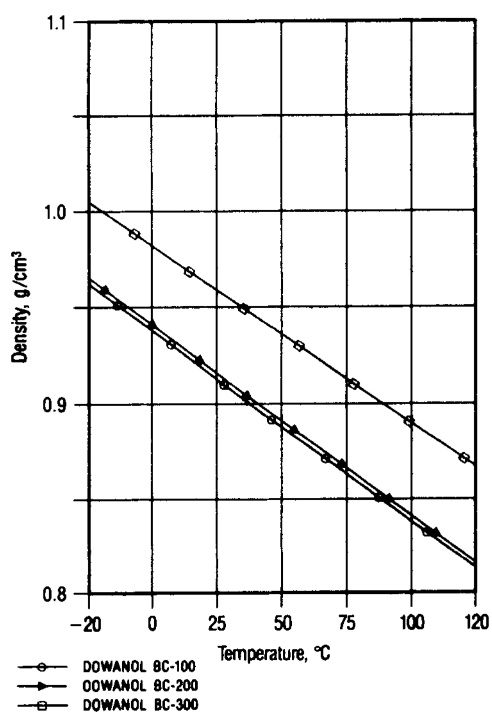
Table 11.65: (continued)

Density (g/cm³) of DOWANOL Products





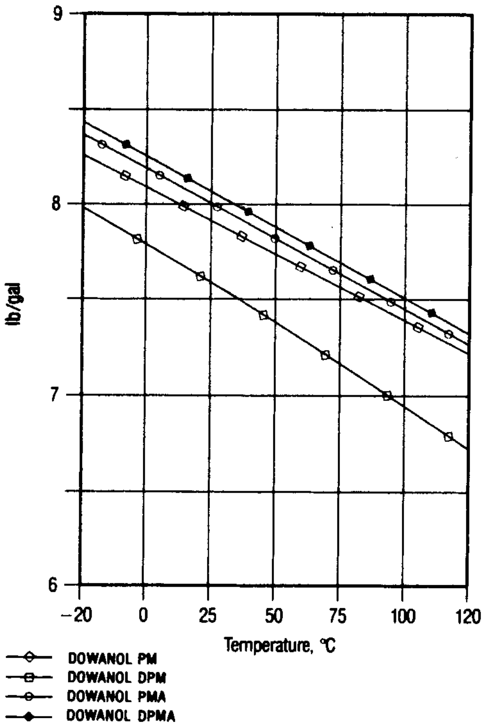


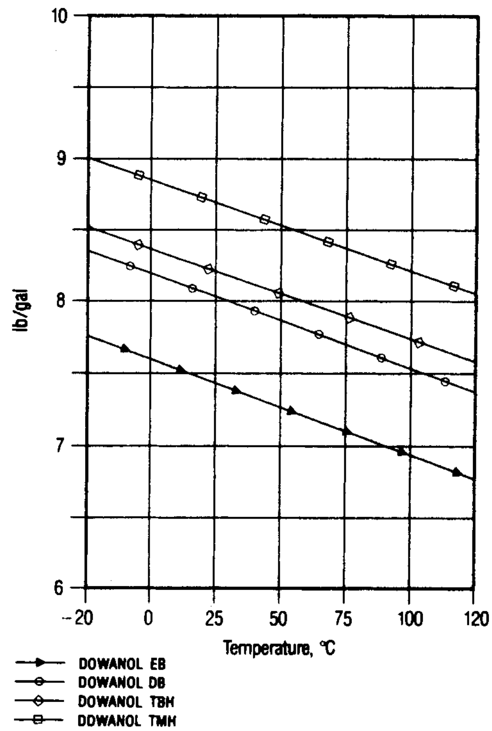


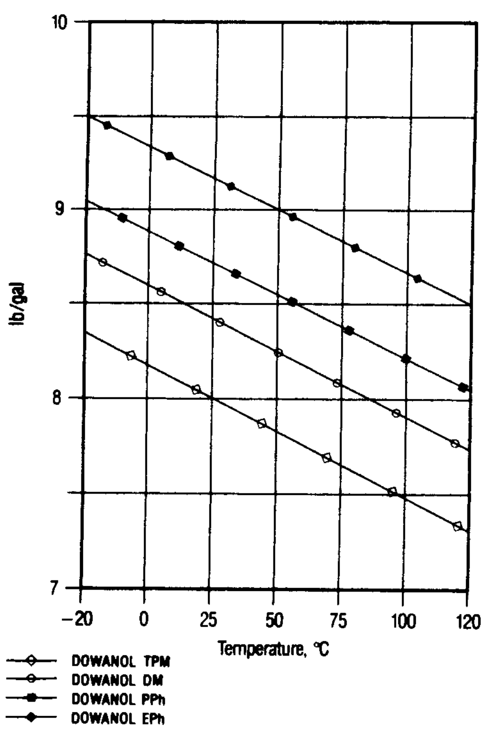
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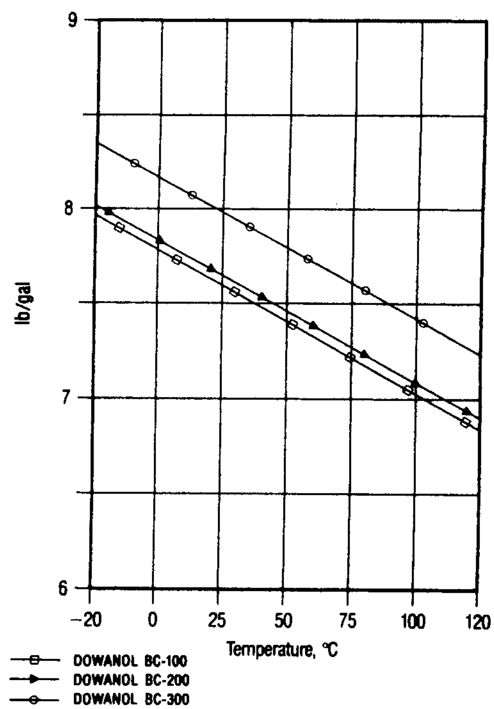
Table 11.65: (continued)

Pounds/Gallon of DOWANOL Products









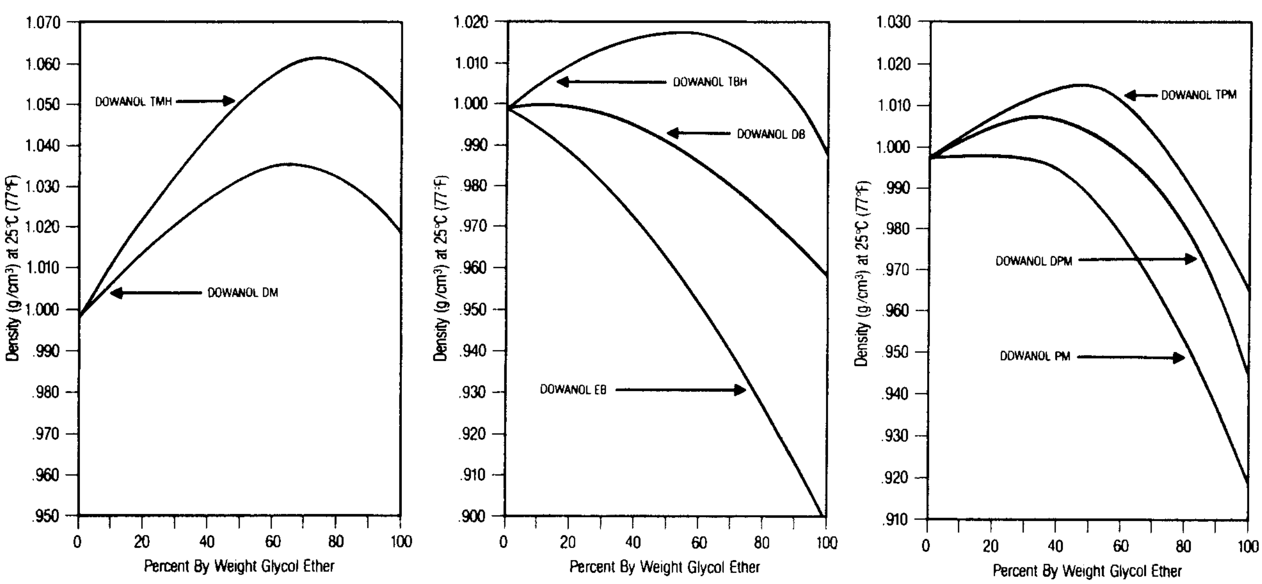
(continued)

Table 11.65: (continued)

Coefficients of Expansion of Liquid DOWANOL Products

DOWANOL	Coefficient of Expansion (per °C)	Coefficient of Expansion (per °F)
PM	0.00100	0.00056
DPM	0.00094	0.00052
TPM	0.00089	0.00049
PMA	0.00097	0.00054
DPMA	0.00100	0.00056
PPh	0.00086	0.00048
BC-100	0.00100	0.00056
BC-200	0.00099	0.00055
BC-300	0.00098	0.00055
EB	0.00086	0.00048
DB	0.00081	0.00045
TBH	0.00079	0.00044
DM	0.00091	0.00051
TMH	0.00079	0.00044
EPh	0.00086	0.00048
DALPAD A	0.00086	0.00048

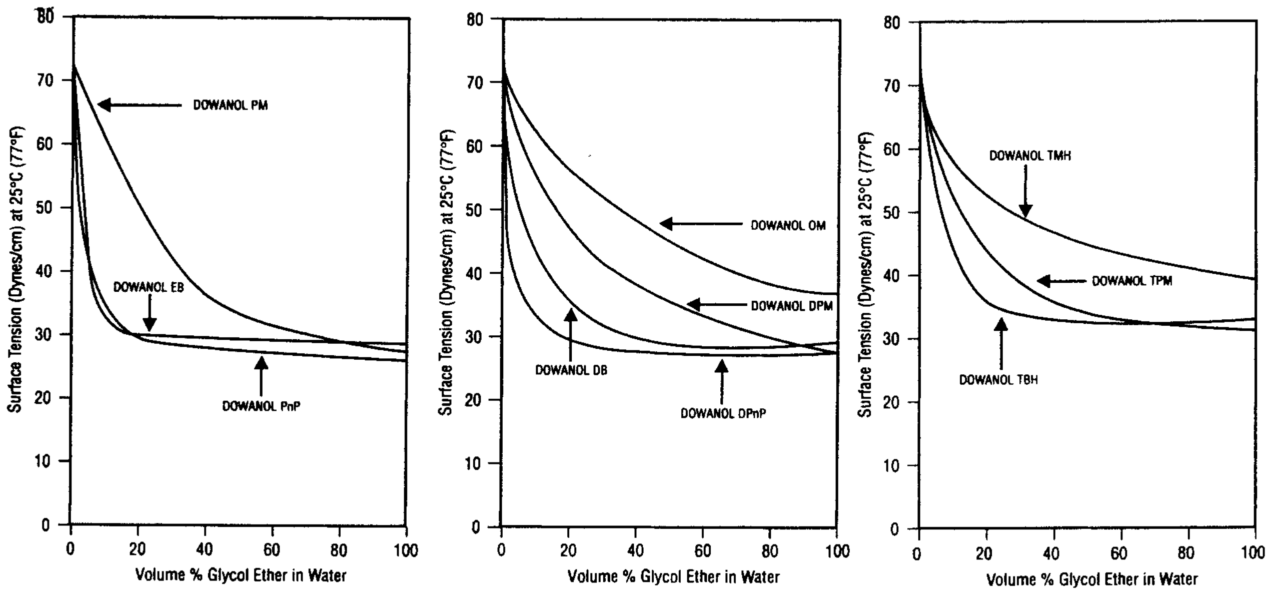
Density (g/cm³) of Aqueous Solutions of DOWANOL Products



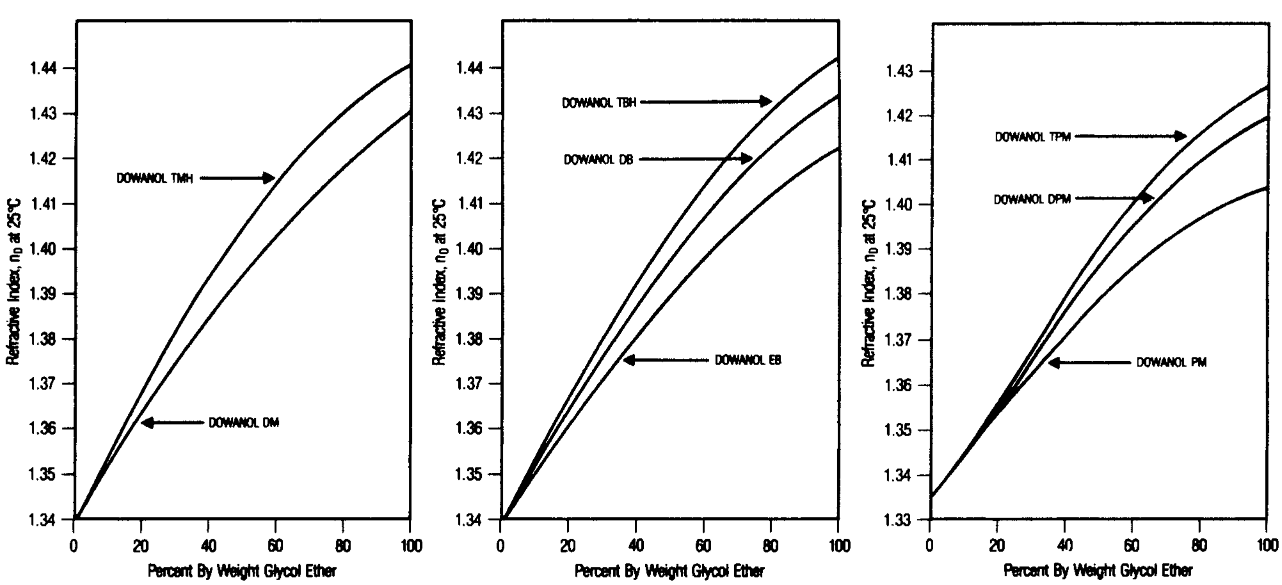
(continued)

Table 11.65: (continued)

Surface Tensions of Aqueous Solutions of DOWANOL Products



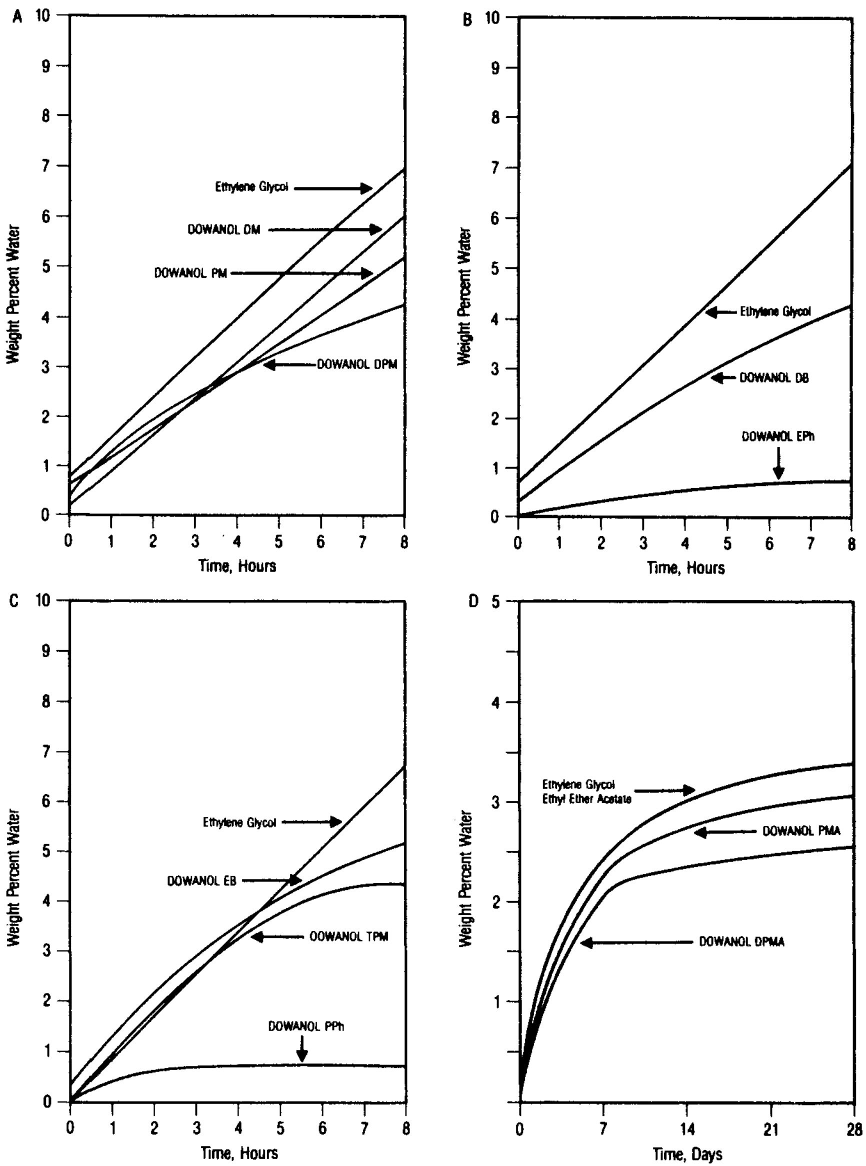
Refractive Indices of Aqueous Solutions of DOWANOL Products



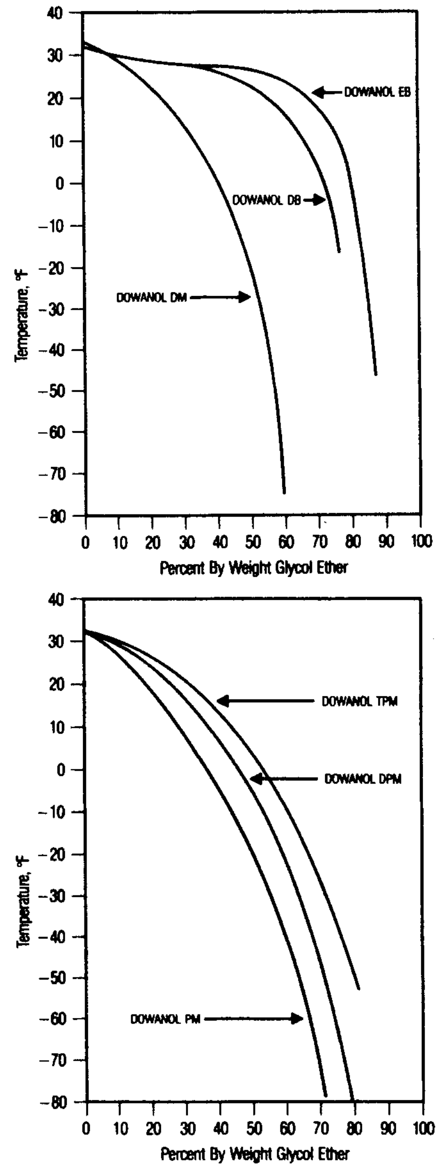
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Table 11.65: (continued)

Hygroscopicity of DOWANOL Products at 21°C (70°F) and 77% Relative Humidity

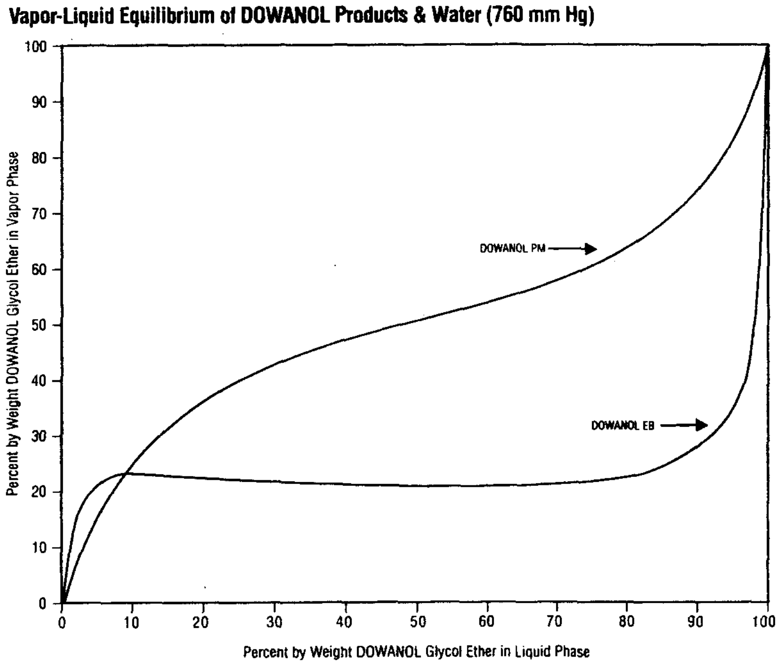


Freezing Points of Aqueous Solutions of DOWANOL Products



(continued

Table 11.65: (continued)



Azeotropes of DOWANOL Products

Component Data		Boiling Point °C at 760 mm Hg for Pure Component	Boiling Point °C at 760 mm Hg for Azeotrope	Azeotropic Data: Composition of Azeotrope	
Component A	Component B			Wt. % A	Wt. % B
DOWANOL EB		171.2			
	Water	100	98.8	20.8	79.2
	Bis (2-chloroethyl) Ether	179.2	170.8	75	25
	Amyl Ether	187.5	169.0	67	33
DOWANOL PM		120.1			
	Water	100	98.3	51.5	48.5
	Toluene	110.7	106.5	30	70

Rubber Swell Properties of DOWANOL Products

	PM	DPM	TPM	EB	DB	DM
Natural Rubber Swell[1]						
Average % Dimension Change	6	7	9	21	11	2
Average % Volume Change	21	26	29	92	32	7
Synthetic Rubber Swell[2]						
Change in Length[3]						
Buna (GR-S)	8	12	12	20	11	1
Butyl	6	9	7	15	7	−1
Neoprene	10	20	22	24	28	7
Change in Width[3]						
Buna (GR-S)	7	11	13	26	14	4
Butyl	3	7	6	16	10	3
Neoprene	10	22	22	24	29	9
Change in Thickness[3]						
Buna (GR-S)	6	10	11	49	34	23
Butyl	5	10	7	33	25	19
Neoprene	42	59	58	60	69	48
Average % Volume Change						
Buna (GR-S)	22	37	40	127	69	30
Butyl	14	28	22	79	47	22
Neoprene	72	133	135	147	178	73

[1] Tests made in manner specified for hydraulic fluids by SAE (Lockhead Wagner FC-666-XO brake fluid cups, 120 hours at 158°F.)
[2] Tests were carried out using cured rubber strips measuring approximately 2 x 1 x 0.11 inch, 120 hours at 158°F.
[3] Average % dimension

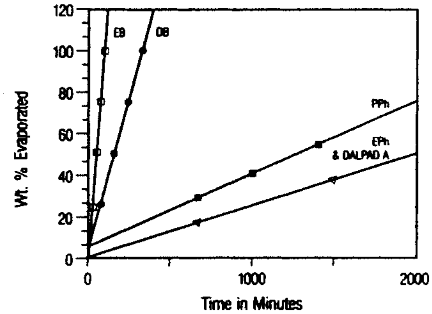
(continued)

Table 11.65: (continued)

Heats of Combustion of DOWANOL Glycol Ethers

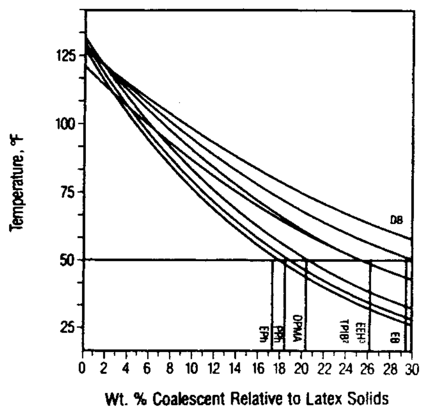
DOWANOL	kcal/mole	kcal/g	BTU/lb
PM	556	6.18	11,115
DPM	961	6.49	11,700
TPM	1,366	6.62	11,900
EB	848	7.18	12,915
DB	1,109	6.84	12,300
DM	670	5.58	10,043
EPh	958	6.93	12,500

Observed Evaporation Rates For DOWANOL EB, DB, PPh, EPh or DALPAD A



Minimum Film Formation Temperature (MFFT) – Coalescent Efficiency

RHOPLEX[1] WL – 91



[1] Trademark of Rohm & Haas Company
[2] 2, 2, 4-trimethyl-1, 3-pentanediol monoisobutyrate
[3] Ethylene glycol mono-2-ethylhexyl ether

Coupling Abilities of DOWANOL Glycol Ethers and Alcohols[1]

Composition of Titrant, Volume %									
PM	DPM	TPM	EB	DB	DM	sec-butanol	isobutanol	n-butanol	ml to couple[1]
			100						32.8
			75			25			34.2
			50			50			37.9
50								50	41.0
	25					75			42.1
				100					42.5
			25			75			48.8
25								75	51.0
	50						50		58.3
						100			60.9
	25						75		61.8
	50					50			63.9
75								25	64.0
		100							67.0
								100	71.0
	75						25		78.8
100									80.0
	75					25			82.1
	100								95.8
							100		104.6
					100				230.0

[1] Milliliters of product required to titrate 10 ml of mineral spirits and 10 ml of water to a clear homogeneous solution at 25°C

(continued

Table 11.65: (continued)

Properties and Performance of DOWANOL Glycol Ethers in Lacquers

DOWANOL	Viscosity of 8% nitrocellulose solutions in DOWANOL glycol ethers, centistokes at 77°F	Blush Conditions[1]				Dilution Ratios[2]		Kauri[3] Butanol Number
		Blush Conditions		No Blush Conditions				
		% Relative Humidity	Temperature °F	% Relative Humidity	Temperature °F	Toluene	Naphtha	
PM	74.18	61	82	56	82	5.2	0.9	Above 500
DPM	158.76	90	82	85	82	4.2	0.8	Above 500
TPM	407.16	95	82	90	82	3.1	0.7	Above 500
EB	160.92	95	82	90	82	5.2	2.2	Above 500
DB	229.32	No blush at 95% rel. hum. and 84°F after one hour				6.5	1.9	Above 500
DM	149.05	61[4]	82	56[4]	82	4.6	Immis-cible	Above 500

[1] Blush resistance tests were carried out by spraying a solution of 92% DOWANOL glycol ether and 8% nitrocellulose on a 6" x 24" glass plate from a distance of eight inches, 30-40 pounds air pressure was used and 30 minutes drying time allowed.

[2] Dilution ratios were determined by dissolving 2 g of dried nitrocellulose in 20 ml of DOWANOL glycol ether and adding toluene or naphtha until the nitrocellulose precipitated. The volume of toluene or naphtha required divided by 20 was taken as the dilution ratio.

[3] Kauri Butanol numbers are determined by adding the material being checked to 20 ml of Kauri Butanol reagent until 10 point type can no longer be read through the solution. The number of ml of material required to reach the endpoint is recorded as the Kauri Butanol number. With all DOWANOL glycol ether products tested, 500 ml were added to the reagent without the endpoint being reached.

[4] DOWANOL DM glycol ether seemed to be quite deliquescent.

Solubility of Resins in DOWANOL Products

	Resin Solubility†									
COMPOUND	PM	DPM	TPM	PMA	DPMA	PPh	EB	DB	DM	EPh
Acrylic Acryloid[1] B-66	●	●	●	●	●	●	●	●	●	●
Acryloid B-72	●	●	●	●	●	●	●	●	●	●
Acryloid B-82	●	●	●	●	●	●	●	●	●	●
Elvacite[2] 2010	●	★	■	●	★	★	○	○	●	★
Epoxy D.E.R.* 651	●	●	●	●	●	●	●	●	●	●
D.E.R. 657	●	●	●	●	●	●	●	●	●	●
Melamine Cymel[3] 303	●	●	●	●	●	●	●	●	●	●
Isocyanate Desmodur[4] N100	●[7]	●[7]	●[7]	●	●	●[7]	●[7]	●[7]	●[7]	●[7]
Nitrocellulose R.S ½ sec	●	●	●	●	●	■	●	●	●	■
R.S. ¼ sec	●	●	●	●	●	★	●	●	●	■
Alkyd Cargill 5710	●	●	●	●	●	●	●	●	●	●
Polyester Cargill 5781	●	●	●	●	●	●	●	●	●	●
Chempol[5] 11-2339	●	●	●	●	●	●	●	●	●	●
Cellulosic CAP-482-0.5	●	★	■	●	●	●	■	■	●	●
CAB-381-2	●	■	■	●	●	●	○	○	●	●
Phenoxy UCAR[6] PKHC	●	●	●	●	●	●	●	●	●	●
Vinyl UCAR VYHH	○	○	○	●	■	■	○	○	■	●

† METHOD: Solubility observations were made after 0.5 g resin and 4.5 ml solvent were agitated for 24 hours.

● Soluble
★ Partially soluble, some undissolved gel particles
■ Partially soluble, many undissolved gel particles
○ Insoluble

(continued)

Table 11.65: (continued)

DOWANOL Glycol Ethers Used in Cleaning Formulations

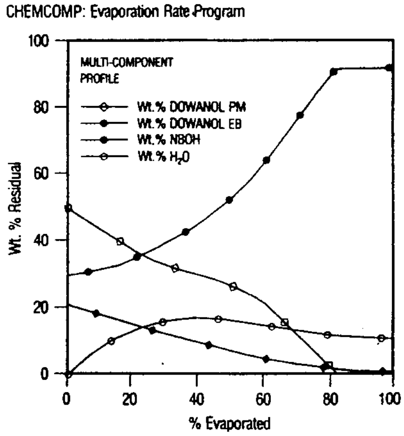
CLEANER	DOWANOL Glycol Ether							
	P-Series				E-Series			
	PM	DPM	TPM	PPh	EB	DB	DM	EPh
Household/Industrial Cleaners Glass Cleaners	•	•			•			
Liquid Soaps		•			•			
Dry Cleaning Soaps	•	•			•	•		
Rug Cleaners	•	•			•	•		
Spotting Fluids	•	•			•	•		
Phosphoric Acid Rust Removers		•	•		•	•	•	•
Aluminum Brighteners		•	•		•	•	•	
Metal Cleaners	•	•			•	•		
Carbon and Grease Removers	•	•			•			
Paint/Varnish/ Silicone Removers	•	•	•	•	•	•	•	•
Ink Removers	•		•		•	•		
Hard Surface Cleaners	•	•	•		•	•		
Oven Cleaners		•	•			•		•
Penetrating Oils			•			•		
White Wall Tire Cleaners		•			•			
Disinfectants/Germicides		•			•	•		•

DOWANOL Glycol Ethers Acceptable as Inert Ingredients in Pesticide Formulations 40 CFR 180.1001, (d) & (e)

Inert Ingredient	Uses
(d) Pesticide formulations applied to growing crops only:	
DOWANOL PM	Solvent.
DOWANOL DPM	Stabilizer.
DOWANOL EB	Solvent, co-solvent.
DOWANOL DB DOWANOL DM	Deactivator for formulations used before crop emerges from soil; stabilizer.
(e) Pesticide formulations applied to animals:	
DOWANOL PM	Deactivator, emollient.
DOWANOL DPM	Surfactants, related adjuvants of surfactants.

Evaporation Rate Program Plot Format

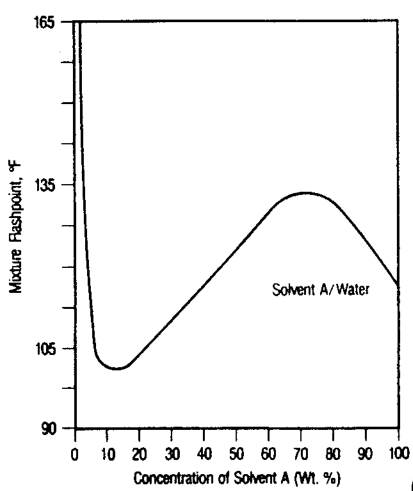
CHEMCOMP: Evaporation Rate Program



Typical Printout from Flash Point Estimator

CHEMCOMP: Flash Point Estimator

Binary Flash Point Curve



(continued)

Table 11.65: (continued)

Typical Printout of Evaporation Rate Program

DOW CHEMICAL U.S.A. SOLVENT EVAPORATION RATE PROGRAM

CASE 1 – SOLVENTS AND COMPOSITIONS

CODE	SOLVENT NAME	COMPOSITION		
		MOLE%	WEIGHT%	VOLUME%
PM	DOWANOL PM GLYCOL ETHER	51.10	50.00	48.37
EB	DOWANOL EB GLYCOL ETHER	22.27	28.57	28.21
NBOH	N-BUTYL ALCOHOL	26.63	21.43	23.43
H_2O	WATER	0.00	0.00	0.00

CODE	SOLVENT NAME	T90 (SEC)	RELATIVE RATE	FP (°F)	DENS (G/CC)	COST ($/LB)
PM	DOWANOL PM GLYCOL ETHER	669.	0.699509	100.	0.916	0.00
EB	DOWANOL EB GLYCOL ETHER	6095.	0.076770	143.	0.898	0.00
NBOH	N-BUTYL ALCOHOL	1064.	0.439783	97.	0.811	0.00
H_2O	WATER	1490.	0.314038		0.997	0.00

ESTIMATED PROPERTIES FOR THE INITIAL BLEND

DENSITY AT 25°C, G/CC	0.888
CLOSED CUP FLASH POINT, °F	103.
SOLUBILITY PARAMETER, SQRT (CAL/CC)	10.4
HYDROGEN BONDING, RELATIVE TO ISOOCTANE = 0	16.4
DIPOLE MOMENT, DEBYE	1.7
90% EVAPORATION TIME, SECONDS	3910.42
RATE RELATIVE TO NBAC AT 90% EVAPORATED	0.119657

DATA SUMMARY – INITIAL AND AIR TEMP = 25.00°C, REL HUMIDITY = 60.00%

0.35% OF SOLVENT LOST DURING SAMPLE INJECTION TIME OF 8.00 SECONDS

% EVAP	0.0	15.0	30.0	45.0	60.0	75.0	90.0
SECONDS	0.	264.	635.	1046.	1522.	2226.	3910.
REL RATE	0.00	0.30	0.25	0.22	0.20	0.18	0.12
FP (F)	104.	125.	134.	142.	150.	161.	165.
WT% PM	49.69	39.75	34.43	29.34	21.12	5.21	0.00
WT% EB	28.65	32.69	38.46	47.08	60.89	83.44	89.97
WT% NBOH	21.33	16.40	11.84	7.67	3.63	0.35	0.00
WT% H_2O	0.33	11.16	15.26	15.92	14.36	10.99	10.03

SELECT PLOT OPTION
1 = NO MORE PLOTS 2 = LINE PRINTER PLOTS 3 = PEN PLOTS

(continued)

Table 11.65: (continued)

Typical Printout of Solvent Blend Program

The calculated values for this solvent blend are:

- Solubility Parameter 8.74
- Hydrogen Bonding Parameter 5.62
- Dipole Moment 1.08

Limits chosen for search are as follows:

- Solubility Parameter .... 8.60 to 8.88
- Hydrogen Bonding Parameter .... 5.50 to 5.80
- Dipole Moment .... 0.95 to 1.50

You have specified 111 solvents to be included in the search for a blend containing 3 components, one of which is PMA.

BLEND #	SOL. PARAM.	H_2 BOND.	DIPOLE MOMENT	SOLV. #1 WT%	SOLV. #2 WT%	SOLV. #3 WT%
1	8.79	5.56	1.12	PMA 60	ACET 5	CHEX 35
2	8.70	5.53	1.42	PMA 45	ACET 25	HEPT 30
3	8.65	5.59	1.35	PMA 50	ACET 20	HEPT 30
4	8.60	5.65	1.29	PMA 55	ACET 15	HEPT 30
5	8.61	5.62	1.44	PMA 45	ACET 25	ISOE 30
6	8.67	5.70	1.46	PMA 45	ACET 25	ISOG 30
7	8.62	5.76	1.40	PMA 50	ACET 20	ISOG 30
8	8.64	5.73	1.47	PMA 45	ACET 25	ISOH 30

FOUND 100 BLENDS THAT MEET LIMITS OUT OF 119,308 CHECKED.

Typical Printout of VOC Program Calculations

VOC Calculations

FORMULATION: Epoxy Modified Acrylic

COMMENTS: Bake Schedule: 350°F, 10 Min.

TYPE OF CALCULATIONS: Dispersion

MATERIAL	DENSITY LB/GAL	FORMULA LB	FORMULA GAL	SOLIDS LB	SOLIDS GAL	VOC LB	VOC GAL
TITANIUM DIOXIDE	34.72	95.5	2.75	95.5	2.75	—	—
ACRYLOID[1] AT-400	8.60	—	—	—	—	—	—
METHYL AMYL KETONE	6.77	15.8	2.33	—	—	15.8	2.33
RESIN SOLID	9.45	47.4	5.02	47.4	5.02	—	—
DER* 661 EPOXY RESIN	9.90	—	—	—	—	—	—
RESIN SOLID	9.90	15.5	1.57	15.5	1.57	—	—
DOWANOL PM	7.56	28.0	3.70	—	—	28.0	3.70
DOWANOL DPM	7.91	6.7	0.85	—	—	6.7	0.85
CYMEL[2] 370	9.80	—	—	—	—	—	—
ISO-BUTANOL	6.68	4.6	0.68	—	—	4.6	0.68
RESIN SOLID	10.47	33.5	3.20	33.5	3.20	—	—
Totals	12.29	247.0	20.10	191.9	12.53	55.1	7.57

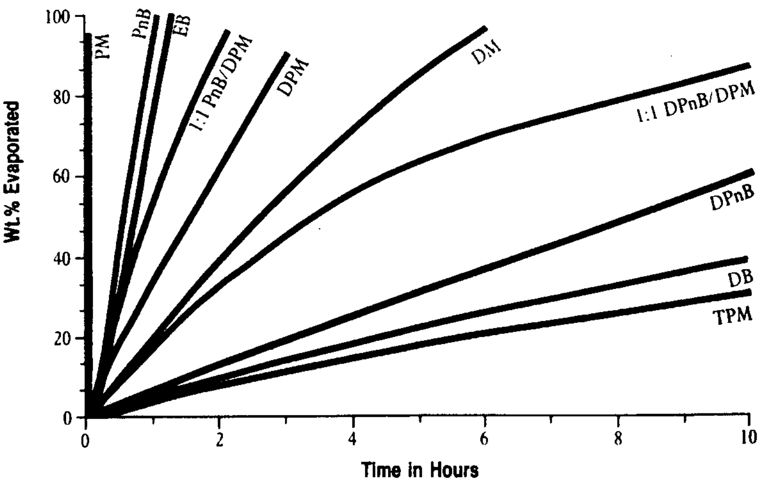
VOC = 2.74 LB/GAL 328.25 G/L

* Trademark of The Dow Chemical Company
[1] Trademark of Rohm & Haas Company
[2] Trademark of American Cyanamid Company

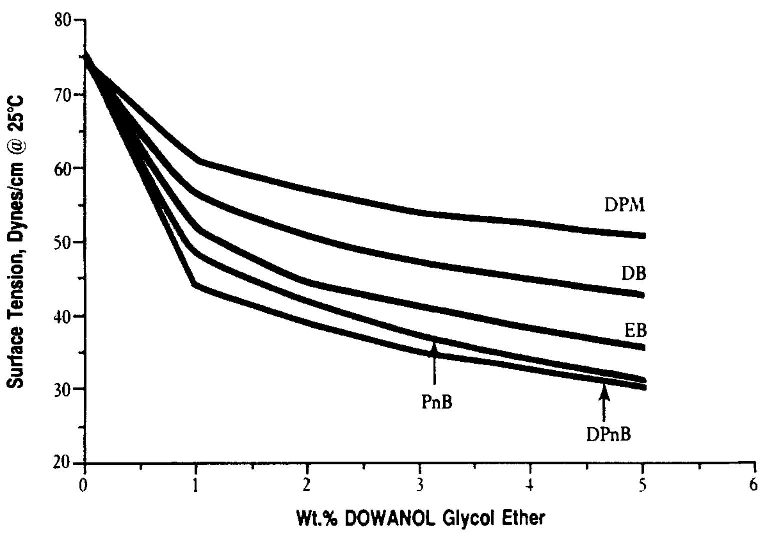
(continued)

Table 11.65: (continued)

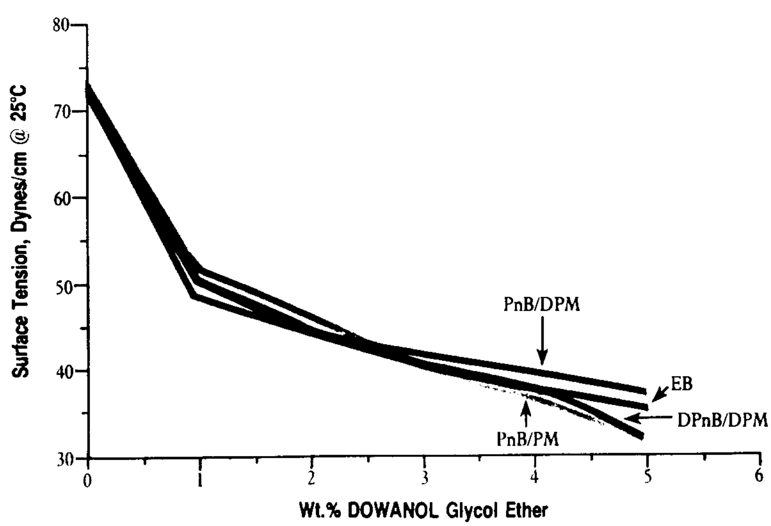
Observed Evaporation Rates of DOWANOL Glycol Ethers



Surface Tension



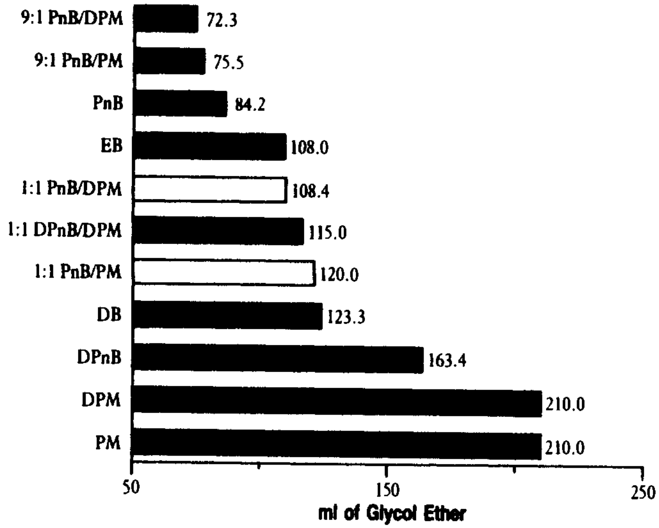
Surface Tension of Blends



(continued)

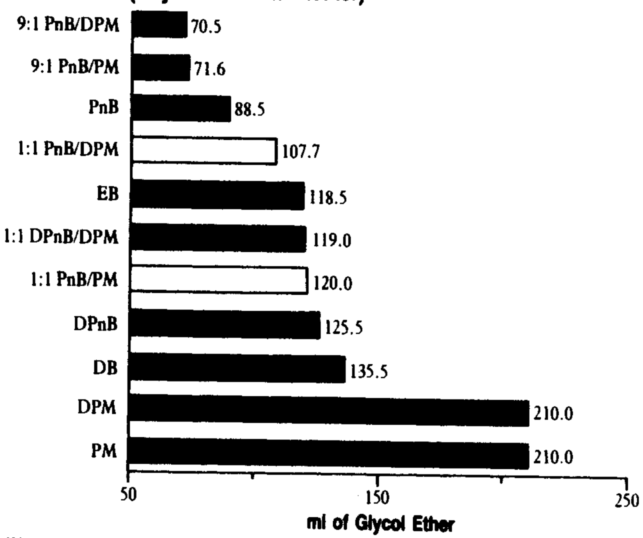
Table 11.65: (continued)

Coupling Performance† of DOWANOL Glycol Ethers (Corn Oil and Water)



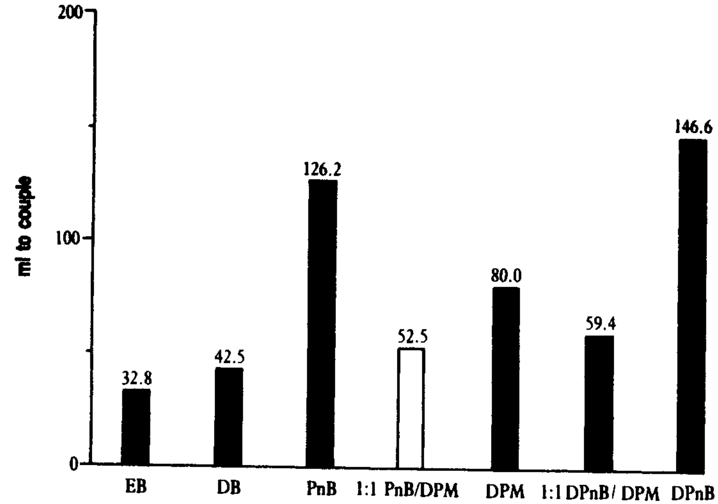
†Volume of glycol ether required to titrate 10ml of corn oil and 10ml of water to a homogeneous solution at 25°C.

Coupling Performance† of DOWANOL Glycol Ethers (Soybean Oil and Water)



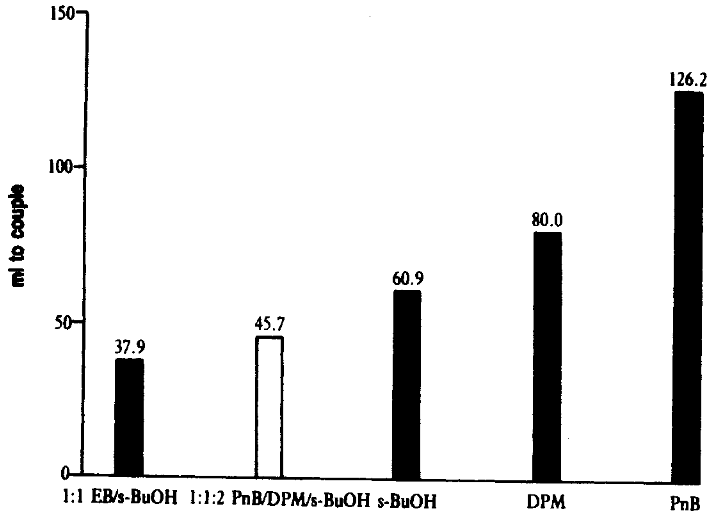
†Volume of glycol ether required to titrate 10ml of soybean oil and 10ml of water to a homogeneous solution at 25°C.

Coupling Performance† (Mineral Spirits and Water)



†Volume of solvent required to titrate 10ml of mineral spirits and 10ml of water at 25°C to obtain a homogeneous solution.

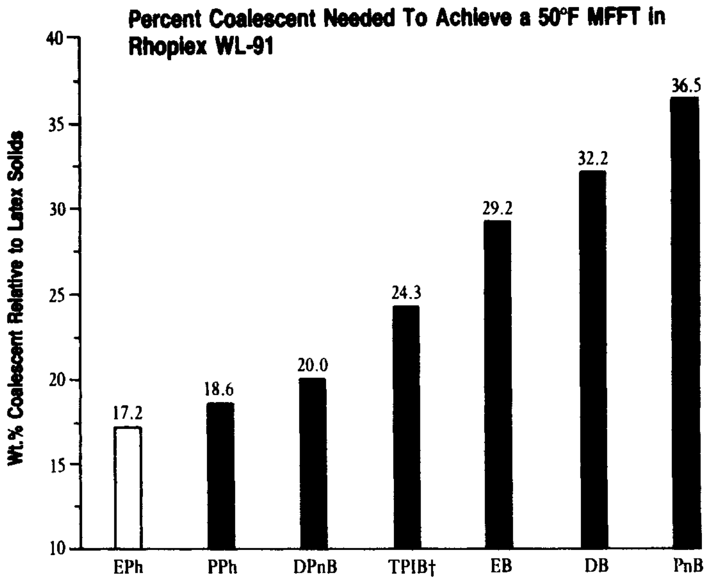
Coupling Performance† (Mineral Spirits and Water)



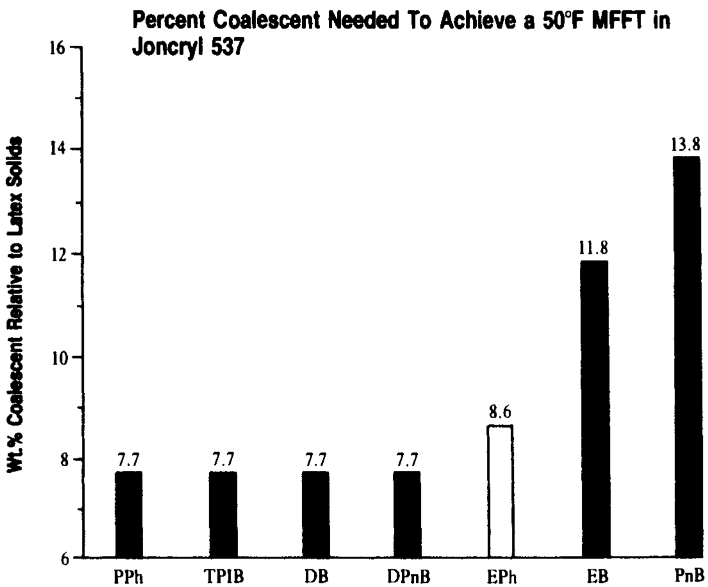
†Volume of solvent required to titrate 10ml of mineral spirits and 10ml of water at 25°C to obtain a homogeneous solution.

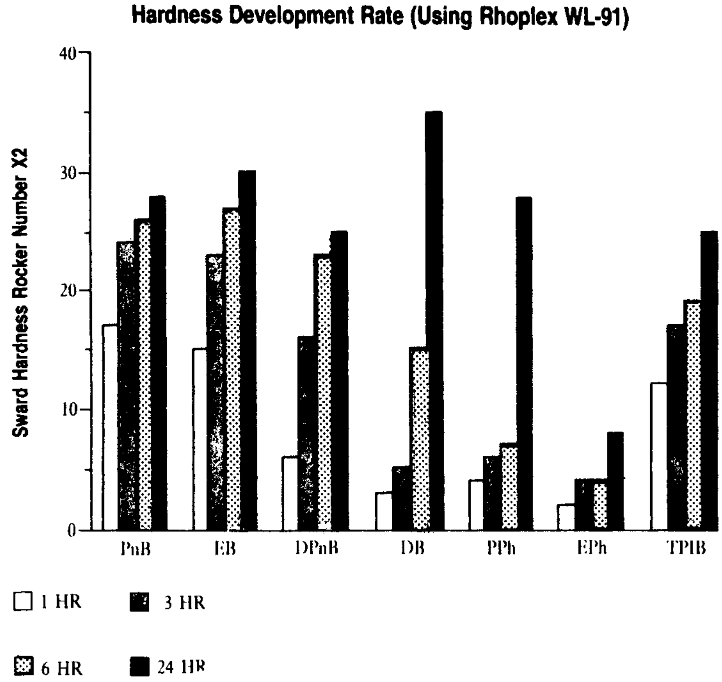
(continued)

Table 11.65: (continued)



†Texanol ester alcohol. Texanol is a trademark of Eastman Chemical.



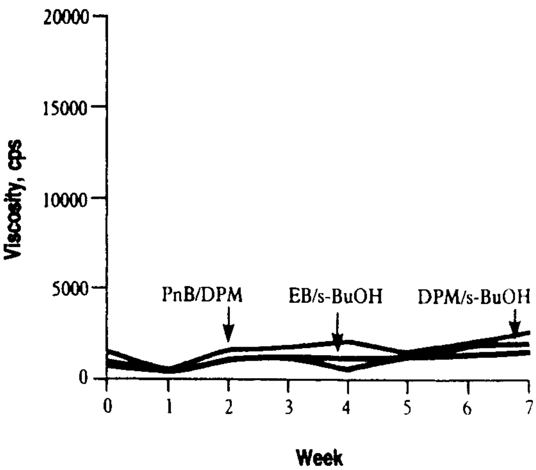


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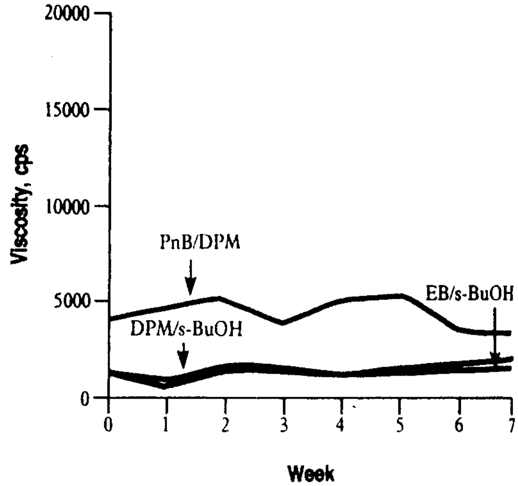
Table 11.65: (continued)

Accelerated Aging Study (at Room Temperature)

Resin A Concentrate

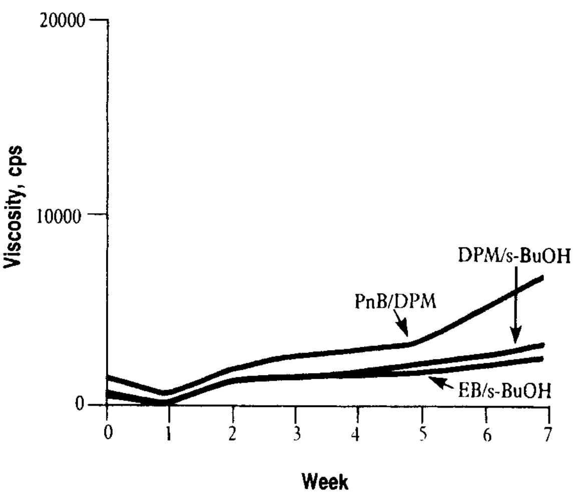


Resin B Concentrate

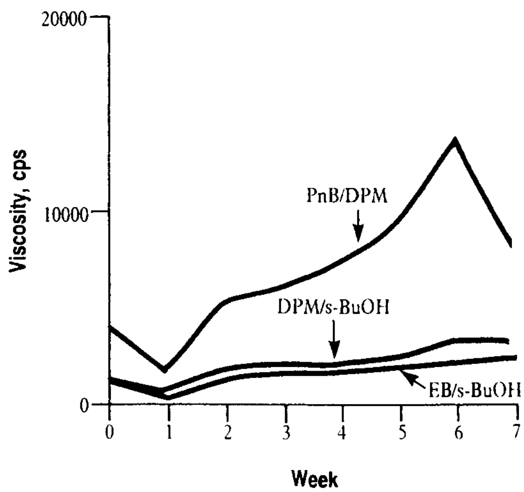


Accelerated Aging Study (at 120°F)

Resin A Concentrate

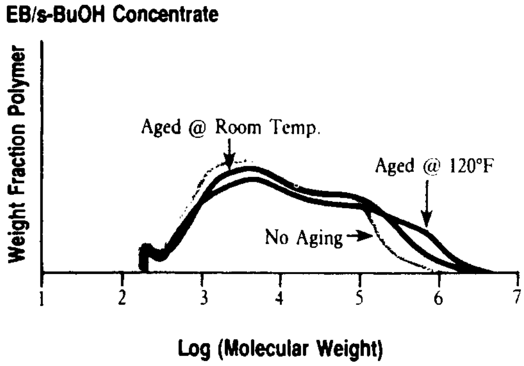


Resin B Concentrate

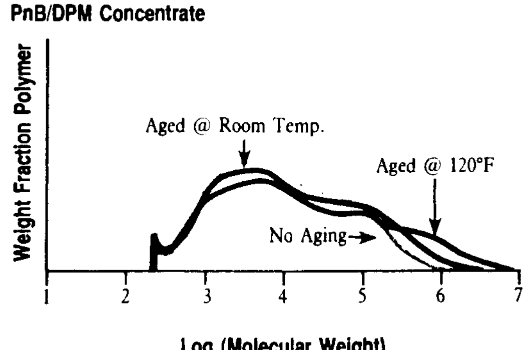


Molecular Weight Distribution (Resin A Concentrate)

EB/s-BuOH Concentrate



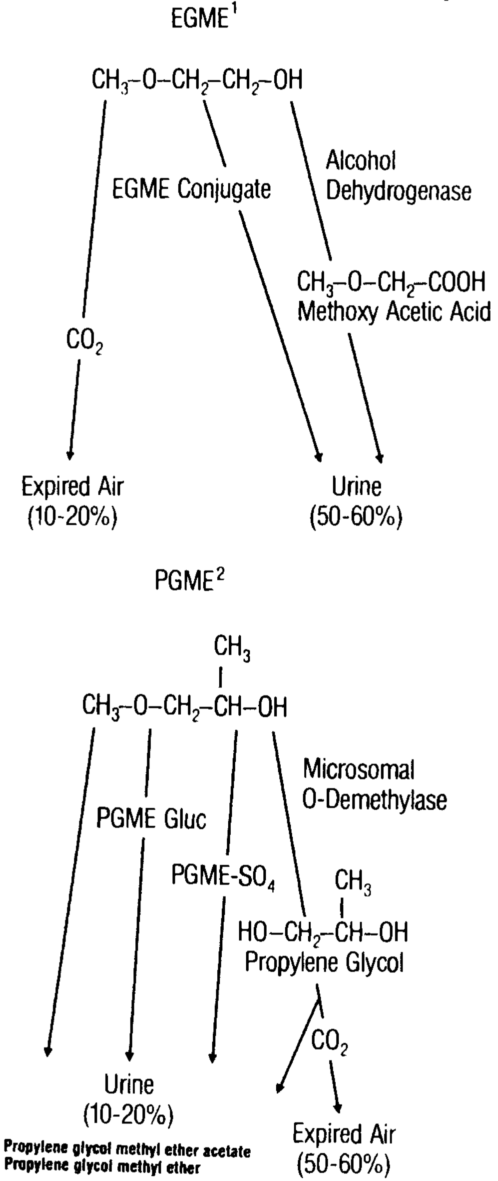
PnB/DPM Concentrate



(continued

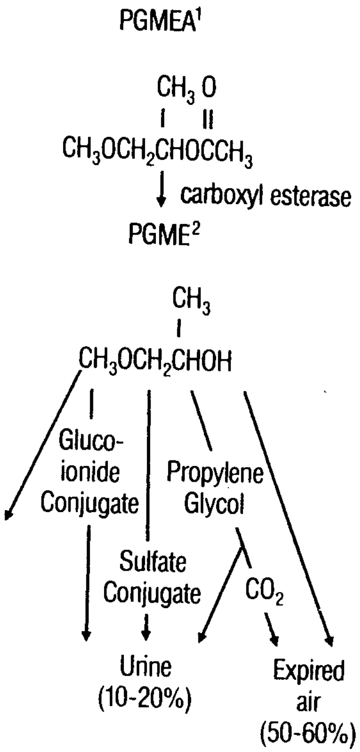
Table 11.65: (continued)

Comparative Metabolism and Disposition of Ethylene Glycol Methyl Ether and DOWANOL PM Propylene Glycol Methyl Ether



[1] Propylene glycol methyl ether acetate
[2] Propylene glycol methyl ether

Metabolism and Disposition of DOWANOL PMA Propylene Glycol Methyl Ether Acetate



[1] Propylene glycol methyl ether acetate
[2] Propylene glycol methyl ether

Table 11.65: (continued)

Glycol Ether Toxicity Summary

Type of Study	Species	Exposure Level	Effects
Propylene Glycol Monomethyl Ether (PM)			
90-day subchronic inhalation study	Rats Rabbits	3000 ppm	CNS depression and slight liver weight increase
		1000 ppm	NOEL
Inhalation teratology studies	Rats	3000 ppm	Maternal toxicity (slight CNS depression, decreased food consumption); slight fetotoxicity
		1500 ppm	NOEL
	Rabbits	3000 ppm	Maternal toxicity (decreased food consumption)
		1500 ppm	NOEL
Dipropylene Glycol Monomethyl Ether (DPM)			
90-day subchronic inhalation study	Rats Rabbits	200 ppm 50 ppm 15 ppm	No treatment-related effects at any level
Inhalation teratology study	Rats Rabbits	300 ppm 150 ppm 50 ppm	No treatment-related effects at any level
4-week dermal study	Rats	1000 mg/kg 100 mg/kg	No treatment-related effects
Tripropylene Glycol Monomethyl Ether (TPM)			
Dermal 90-day subchronic study	Rabbits	10 ml/kg 4 ml/kg 3 ml/kg 1 ml/kg	Mortality at high dose; narcosis at lower doses; mild skin irritation
Inhalation teratology study	Rats	Aerosols of 1.0 mg/L 0.3 mg/L 0.1 mg/L	Maternal toxicity at high dose; embryo/fetotoxicity and teratogenicity NOEL=1.0 mg/L
Propylene Glycol Monomethyl Ether Acetate (PMA)			
Inhalation 9-day subacute study	Rats Mice	3000 ppm 1000 ppm 300 ppm	Mild, high-dose liver effects similar to those seen with DOWANOL PM; evidence of upper respiratory tract irritation in all exposures in mice and high exposure in rats
Inhalation teratology study	Rats	4000 ppm 400 ppm	Embryo/fetotoxity and teratogenicity NOEL=4000 ppm slight maternal toxicity
Dipropylene Glycol Monomethyl Ether Acetate (DPMA)			
No subchronic, teratogenicity, or reproductive studies have been conducted. However, this compound is likely to rapidly and completely convert to dipropylene glycol monomethyl ether after absorption into the body. Thus, its systemic toxicity would be expected to be similar to dipropylene glycol monomethyl ether.			
Propylene Glycol n-Butyl Ether (PnB)			
13-week subchronic dermal study	Rabbits	2 ml/kg/day of 57% soln. 5.7% soln. 0.57% soln.	Skin effects at all levels; no systemic effects at any level

(continued)

Table 11.65: (continued)

Type of Study	Species	Exposure Level	Effects
Propylene Glycol n-Butyl Ether (PnB)			
13-week subchronic dermal study	Rats	1 ml/kg/day (880 mg/kg/day) 0.3 ml/kg/day 0.1 ml/kg/day	Minor skin effects at all levels; no systemic effects at any level
13-week subchronic oral study	Rats	1000 mg/kg 350 mg/kg 100 mg/kg	Increased liver and kidney weights at 1000 mg/kg NOEL=350 mg/kg
Dermal teratology study	Rats	1 ml/kg/day 0.3 ml/kg/day	No embryo/fetotoxicity or teratogenicity at any level
	Rabbits	100 mg/kg/day 40 mg/kg/day 10 mg/kg/day	No embryo/fetotoxicity or teratogenicity at any level
Dipropylene Glycol n-Butyl Ether (DPnB)			
13-week subchronic diet study	Rats	1000 mg/kg/day	Slight effects to body weights, clinical chemistries, and liver weights
		450 mg/kg/day	Capacity changes; not considered toxic effects
		200 mg/kg/day	NOEL
13-week subchronic dermal study	Rats	1 ml/kg/day	Skin effects; effects to body weights, food consumption, and liver weights
		0.3 ml/kg/day	Effects to body weights and food consumption
		0.1 ml/kg/day	NOEL for systemic effects
Dermal teratology study	Rats	1 ml/kg/day 0.3 ml/kg/day 0.1 ml/kg/day	Minor maternal skin effects at all levels; no embryo/fetotoxicity or teratogenicity at any level
Propylene Glycol Monophenyl Ether (PPh)			
28-day subchronic dermal study	Rats	1000 mg/kg 300 mg/kg 100 mg/kg	No evidence of systemic toxicity (NOEL=1000 mg/kg); mild, transient dermal irritation at all doses
Ethylene Glycol Monobutyl Ether (EB)			
90-day subchronic inhalation study	Rats	77 ppm	Blood effects
		25 ppm	NOEL
90-day subchronic dermal study	Rabbits	150 mg/kg 50 mg/kg 10 mg/kg	No treatment-related effects at any level
Teratology studies	Rats	300 ppm	Maternal and embryo lethality
		200 ppm 100 ppm	Maternal toxicity, embryo toxicity, fetotoxicity
		50 ppm	NOEL
	Rabbits	200 ppm	Maternal toxicity, embryo toxicity
		100 ppm	NOEL
Diethylene Glycol Mono-n-Butyl Ether (DB)			
90-day subchronic dermal study	Rats	2000 mg/kg 666 mg/kg	Slight hemoglobinuria
		200 mg/kg	NOEL
90-day subchronic reproduction study	Rats	2000 mg/kg 666 mg/kg 200 mg/kg	No reproductive effects at any level

(continued)

Table 11.65: (continued)

Type of Study	Species	Exposure Level	Effects
Diethylene Glycol Mono-n-Butyl Ether (DB)			
Dermal teratology study	Rabbits	1000 mg/kg	NOEL for embryo toxicity and fetotoxicity
90-day subchronic neurotoxicity study	Rats	2000 mg/kg	NOEL
Triethylene Glycol Mono-n-Butyl Ether and Higher Homologs (TBH)			
Note: *Toxicity tests described below have been conducted only with triethylene glycol mono-n-butyl ether.*			
3-week dermal study	Rabbits	1000 mg/kg	Skin irritation; no systemic toxicity
Oral developmental toxicity screen	Rats	1000 mg/kg 250 mg/kg	No treatment-related effects
Diethylene Glycol Monomethyl Ether (DM)			
90-day subchronic inhalation study	Rats	216 ppm 100 ppm 30 ppm	No treatment-related effects at any level
Dermal teratology study	Rabbits	750 mg/kg	Maternal toxicity; slightly embryotoxic and fetotoxic
		250 mg/kg	Slightly fetotoxic
		50 mg/kg	NOEL
Triethylene Glycol Monomethyl Ether and Higher Homologs (TMH)			
Note: *Toxicity tests described below have been conducted only with triethylene glycol monomethyl ether.*			
90-day oral subchronic study	Rats	4000 mg/kg 1200 mg/kg 400 mg/kg	NOEL for neurotoxicity 4000 mg/kg; NOEL for systemic toxicity 400 mg/kg
90-day dermal subchronic study	Rats	4000 mg/kg 1200 mg/kg 400 mg/kg	NOEL 4000 mg/kg
Oral teratology study	Rats	5000 mg/kg 2500 mg/kg 1250 mg/kg 625 mg/kg	Slight variations in fetal skeletons at 1250 mg/kg; fetal NOAEL 1250 mg/kg
Oral teratology study	Rabbits	1500 mg/kg 1000 mg/kg 500 mg/kg 250 mg/kg	Fetal NOAEL 1500 mg/kg
Oral developmental neurotoxicity study	Rats	3000 mg/kg 1650 mg/kg 300 mg/kg	Neurotoxicity NOEL 1650 mg/kg; developmental NOEL 300 mg/kg
Ethylene Glycol Monophenyl Ether (EPh)			
90-day subchronic dermal study	Rabbits	500 mg/kg 150 mg/kg 50 mg/kg	Minor skin effects; no evidence of systemic toxicity at any level
Dermal teratology study	Rabbits	1000 mg/kg 600 mg/kg 300 mg/kg	Maternal death at high dose, maternal toxicity at 600 mg/kg; no embryo/fetotoxicity or teratogenicity at any level
Oral 5-week reproduction study	Mice	2000 mg/kg 1000 mg/kg 500 mg/kg	No reproductive effects at any level

NOEL: No Observed Effect Level
NOAEL: No Observed Adverse Effect Level

(continued)

Table 11.65: (continued)

Exposure Guidelines for DOWANOL Glycol Ethers and Acetates

DOWANOL	CHEMICAL NAME	OSHA[2] Standard	ACGIH[3] TLV[4]	Dow Internal Industrial Hygiene Guide
P-Series				
PM	Propylene glycol methyl ether	100 ppm[5]	100 ppm	NE
DPM	Dipropylene glycol methyl ether	100 ppm[5] (skin)[6]	100 ppm	NE
PMA	Propylene glycol methyl ether acetate	NE[7]	NE	NE
E-Series				
EB	Ethylene glycol n-butyl ether	25 ppm[5] (skin)	25 ppm (skin)	NE
DB	Diethylene glycol n-butyl ether	NE	NE	35 ppm
DM	Diethylene glycol methyl ether	NE	NE	30 ppm
EPh	Ethylene glycol phenyl ether	NE	NE	25 ppm (skin)

Environmental Data for DOWANOL Products

DOWANOL	COD (part/part)		BOD/theory %[3]		
	Theory[1]	$K_2Cr_2O_7$[2]	5 days	10 days	20 days
P-Series					
PM	1.95	1.84	0	22	58
DPM	2.06	2.02	0	0	31
TPM	2.09	2.02	0	1	52
PMA	1.82	1.74	20	57	62
DPMA	1.94	1.98	2	28	62
PPh	2.30	2.26	3	37	52
E-Series					
EB	2.30	2.21	5	57	72
DB	2.17	2.06	2	13	47
TBH	2.10	2.02	0	5	24
DM	1.73	1.66	0	21	66
TMH	1.76	1.75	0	14	23
EPh	2.18	2.12	2	71	80
DALPAD A	2.18	2.12	2	71	80

[1] Theoretical Oxygen Demand (ThOD) calculated for complete oxidation to carbon dioxide and water.

[2] Chemical Oxygen Demand (COD) determined by oxidation with acidic dichromate.

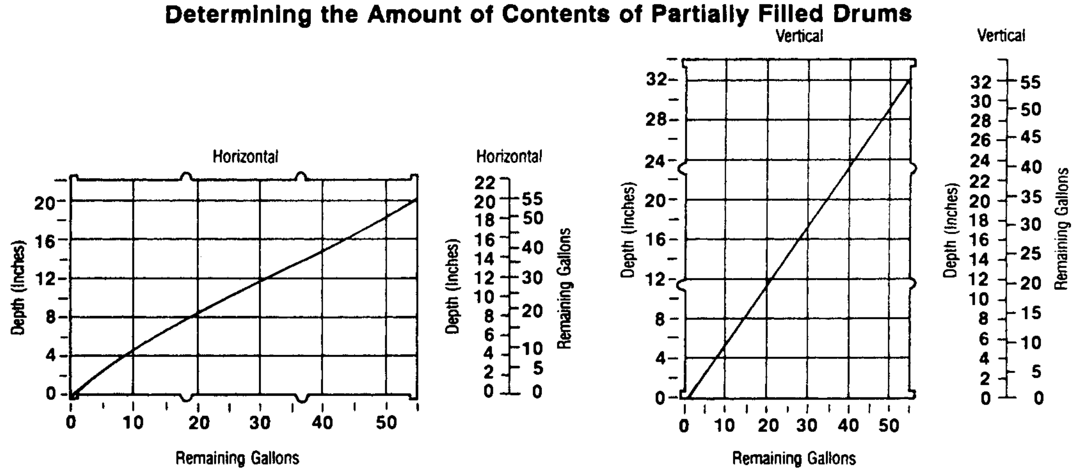
[3] Biochemical Oxygen Demand (BOD) expressed as a percentage of Theoretical Oxygen Demand. A BOD 20 of >50% indicates the product will be largely removed in a biological wastewater treatment plant. A BOD 20 of 10-50% indicates it will be partially removed.

Table 11.65: (continued) **Food Additive Status of DOWANOL Glycol Ethers**

Regulation Number (21 CFR)	Title	PM	DPM	TPM	EB	DB	DM	EPh
181.30	Substances used in the manufacture of paper and paperboard products used in food packaging (prior sanctioned food ingredients).	•	•	•				
176.300	Slimicides (for use in the manufacture of paper and paperboard). Adjuvant substances permitted to be used in the preparation of slimicides.	•	•	•	•	•		
176.210	Defoaming agents used in the manufacture of paper and paperboard.				•			
175.105	Adhesives.	•	•	•	•	•	•	•
178.1010	Sanitizing solutions. Paragraph (a)(4): an aqueous solution containing iodine, butoxy monoether of mixed (ethylene-propylene) polyalkylene glycol having a cloud point of 90°C-100°C in 0.5% aqueous solution and an average molecular weight of 3300, ethylene glycol monobutyl ether, and diethylene glycol monoethyl ether, together with components generally recognized as safe.				•			
176.180	Components of paper and paperboard in contact with dry food.					•		
177.1650	Polysulfide Polymer-Polyepoxy resins. Paragraph (a)(3): for use as a solvent.				•			
173.315	Chemicals used in washing or to assist in the lye peeling of fruits and vegetables. Paragraph (a)(3): for use in flume water for washing sugar beets prior to the slicing operation (not to exceed 1 ppm in the flume water).				•			

NOTE: This information is for use as a general guideline. The regulations should be consulted for complete details.

Determining the Amount of Contents of Partially Filled Drums



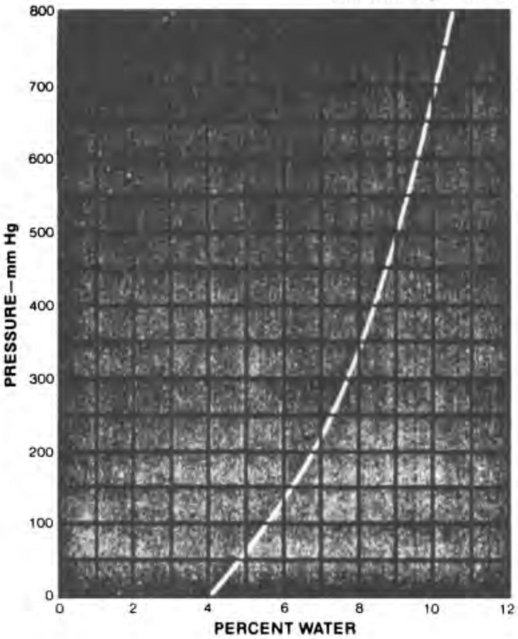
Product Shelf Life

Product/Shelf Life	Lot Number System	Conditions of Temperature and Storage	Deterioration Characteristics
DOWANOL PM, DPM, TPM, EB, DB, DM glycol ether products 18 months – Drums 6 months – Bulk	Standard	Normal conditions – Store below 90°F. Material is hygroscopic; should be in closed containers. Aluminum containers should be avoided.	Lowering of pH – possible rise in color on prolonged standing.
DOWANOL PPh, EPh glycol ether products 18 months – Drums 6 months – Bulk	Standard	Store below 110°F. Aluminum containers should be avoided.	Develops yellow color.

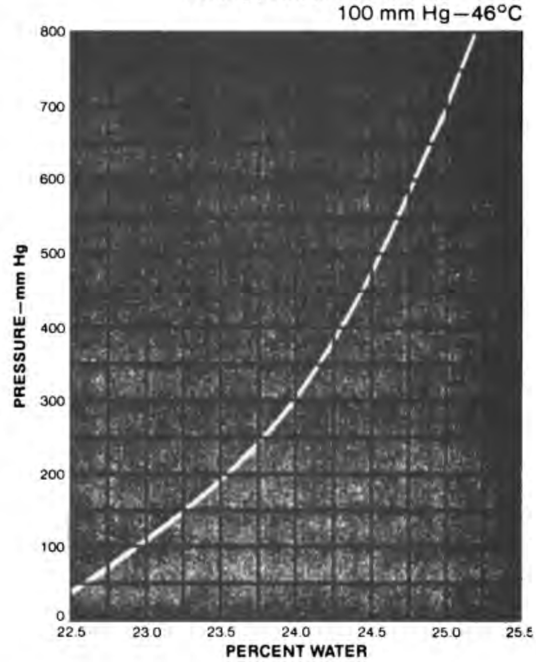
Table 11.66: GLYME Azeotropic Vapor Pressure and Solubility Data *(21)*

AZEOTROPIC DATA

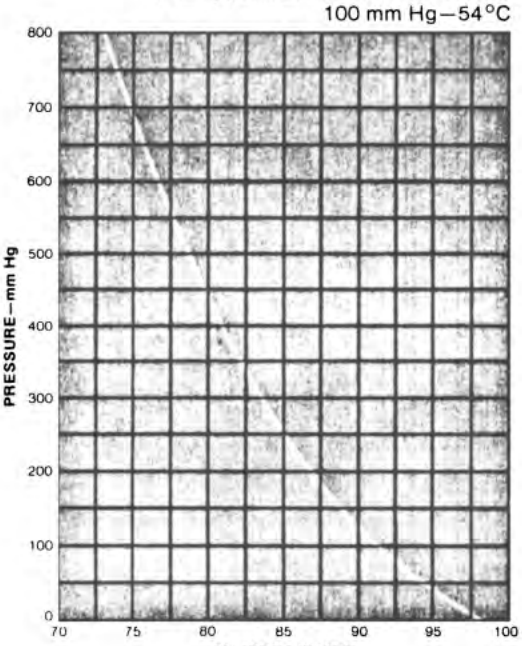
MONOGLYME
Boiling point at 760 mm Hg—76°C
100 mm Hg—30°C



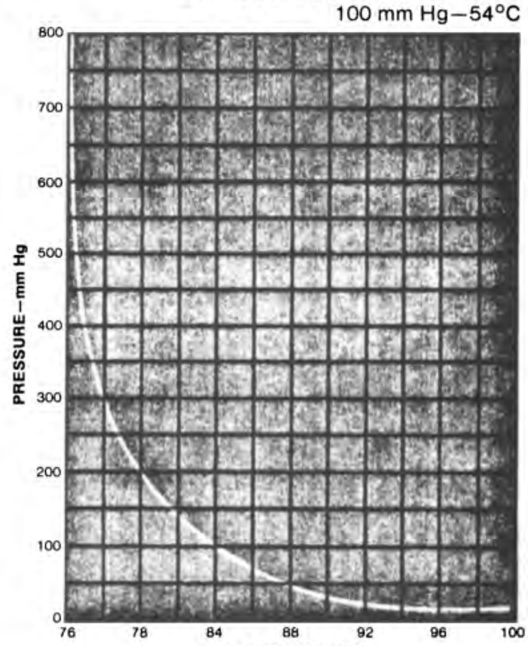
ETHYL GLYME
Boiling point at 760 mm Hg—90°C
100 mm Hg—46°C



DIGLYME
Boiling point at 760 mm Hg—99.5°C
100 mm Hg—54°C



ETHYL DIGLYME
Boiling point at 760 mm Hg—98°C
100 mm Hg—54°C



**Butyl Diglyme, Triglyme, and Tetraglyme do not form azeotropes with water.*

(continued)

Table 11.66: (continued)

POLYMER SOLUBILITY

The solubility of various plastic and elastomeric materials in glymes was determined by placing 10 grams of sample in 100ml of the glyme at 21°C. The samples were examined after one week.

U – Unaffected
A – Attacked (noticeable softening; some swelling)
S – Soluble (10% or more; extreme swelling to gellation)

	MONOGLYME	ETHYL GLYME	DIGLYME	ETHYL DIGLYME	BUTYL DIGLYME	TETRAGLYME
PLASTICS						
Acrylate						
Acrylate ester	S		S			S
Polymethyl methacrylate	S		S			S
Vinyl						
Polyvinyl acetate	S		S			S
Polyvinyl chloride	A	A	A	A	U	A
Chlorinated polyvinyl chloride		A	S	A	U	
Polyvinyl chloride acetate	A	S	A	S	A	A
Polyvinyl alcohol	U	A	U	U	U	U
Polyvinylidene chloride	U	U	A	U	U	A
Cellulose						
Cellulose acetate	S		S			S
Cellulose acetate butyrate	S	A	S	A	U	S
Cellulose nitrate	S		S			S
Methyl cellulose	S	A	S	A	U	S
Condensation Polymers						
Phenol formaldehyde, cast	A		A			A
Nylon	U	U	U	U	U	U
Polyester	U	U	U	U	U	U
Polyurethane	A	A	S	A	U	S
Polycarbonate	A	U	A	A	U	A
Polyolefins						
Polyethylene	U	U	U	U	U	U
Polystyrene	A		A			A
Polytetrafluoroethylene	U	U	U	U	U	U
ELASTOMERS						
Neoprene	S	S	S	S	S	S
EVA	A	A	A	A	A	U
Nitrile Rubber (NBR)	S	S	S	S	A	S
Natural Rubber	S	S	A	S	S	A
EPDM	U	A	U	A	A	A
SBR	S	S	S	S	S	A

VAPOR PRESSURE/ TEMPERATURE RELATIONSHIPS

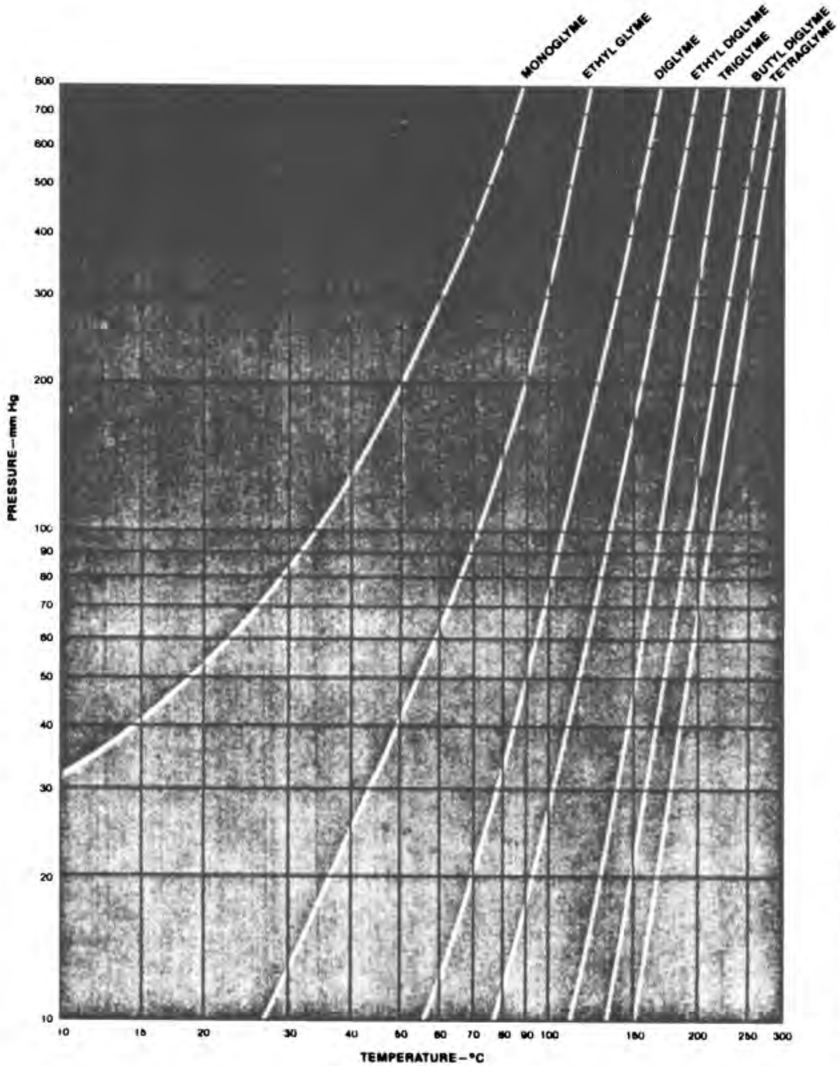


Table 11.67: Union Carbide Glycol Ethers *(19)*

Product Family Order

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F[(a)]	Vapor Pressure, mm Hg at 20°C
Methyl CELLOSOLVE Solvent	76.1	124.5	-85	103	6.2
Methyl CARBITOL Solvent	120.2	194.0	-85	188[(d)]	0.1
Methoxytriglycol	164.2	249.0	-44	238[(d)]	< 0.01
CELLOSOLVE Solvent	90.1	134.9	-90	108	4.1
CARBITOL Solvent	134.2	201.6	-78[(c)]	182[(d)]	0.08
Ethoxytriglycol	178.2	255.9	-19	255	< 0.01
Propyl CELLOSOLVE Solvent	104.2	150.1	-90	135[(d)]	1.6
Butyl CELLOSOLVE Solvent	118.2	171.2	-70	160[(d)]	0.6
Butyl CARBITOL Solvent	162.2	230.6	-68	214	0.01
Butoxytriglycol	206.3	279.8[(e)]	-48	276[(d)]	< 0.01
Hexyl CELLOSOLVE Solvent	146.2	208.1	-50	179	0.05
Hexyl CARBITOL Solvent	190.3	259.1	-40	271[(d)]	<0.01

Boiling Point Order

Solvent	Formula Molecular Weight	Boiling Point, °C	Freezing Point, °C	Flash Point, °F[(a)]	Vapor Pressure, mm Hg at 20°C
Methyl CELLOSOLVE Solvent	76.1	124.5	-85	103	6.2
CELLOSOLVE Solvent	90.1	134.9	-90	108	4.1
Propyl CELLOSOLVE Solvent	104.2	150.1	-90	135[(d)]	1.6
Butyl CELLOSOLVE Solvent	118.2	171.2	-70	160[(d)]	0.6
Methyl CARBITOL Solvent	120.2	194.0	-85	188[(d)]	0.1
CARBITOL Solvent	134.2	201.6	-78[(c)]	182[(d)]	0.08
Hexyl CELLOSOLVE Solvent	146.2	208.1	-50	179	0.05
Butyl CARBITOL Solvent	162.2	230.6	-68	214	0.01
Methoxytriglycol	164.2	249.0	-44	238[(d)]	< 0.01
Ethoxytriglycol	178.2	255.9	-19	255	< 0.01
Hexyl CARBITOL Solvent	190.3	259.1	-40	271[(d)]	< 0.01
Butoxytriglycol	206.3	279.8[(e)]	-48	276[(d)]	< 0.01

Product Family Order

Solvent	Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution[(b)]
Methyl CELLOSOLVE Solvent	0.966	8.04	0.00094	100	100	62	32.1	54.3
Methyl CARBITOL Solvent	1.023	8.51	0.00086	100	100	1.5	35.9	54.3
Methoxytriglycol	1.050	8.74	0.00084	100	100	0.04	34.7	48.4
CELLOSOLVE Solvent	0.931	7.74	0.00097	100	100	41	29.4	47.1
CARBITOL Solvent	0.991	8.25	0.00090	100	100	1.3	35.2	49.6
Ethoxytriglycol	1.025	8.53	0.00086	100	100	0.04	32.2	45.7
Propyl CELLOSOLVE Solvent	0.913	7.60	0.00095	100	100	21	26.3	32.3
Butyl CELLOSOLVE Solvent	0.902	7.50	0.00092	100	100	7.8	28.6	28.9
Butyl CARBITOL Solvent	0.954	7.94	0.00088	100	100	0.24	31.0	33.2
Butoxytriglycol	0.989	8.19	0.00085	100	100	< 0.1	30.0	32.2
Hexyl CELLOSOLVE Solvent	0.889	7.40	0.00086	1.00	18.80	0.82	30.3	28.5[(g)]
Hexyl CARBITOL Solvent	0.935	7.78	0.00084	3	56.30	0.03	29.2[(f)]	—

Boiling Point Order

Solvent	Specific Gravity, 20/20°C	Pounds Per Gallon	Coefficient of Expansion at 20°C	Solubility at 20°C, % by wt: In Water	Solubility at 20°C, % by wt: Water In	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Neat Product	Surface Tension at 25°C, dynes/cm: 25% Aq. Solution[(b)]
Methyl CELLOSOLVE Solvent	0.966	8.04	0.00094	100	100	62	32.1	54.3
CELLOSOLVE Solvent	0.931	7.74	0.00097	100	10	41	29.4	47.1
Propyl CELLOSOLVE Solvent	0.913	7.60	0.00095	100	100	21	26.3	32.3
Butyl CELLOSOLVE Solvent	0.902	7.50	0.00092	100	100	7.8	28.6	28.9
Methyl CARBITOL Solvent	1.023	8.51	0.00086	100	100	1.5	35.9	54.3
CARBITOL Solvent	0.991	8.25	0.00090	100	100	1.3	35.2	49.6
Hexyl CELLOSOLVE Solvent	0.889	7.40	0.00086	1.00	18.80	0.82	30.3	28.5[(g)]
Butyl CARBITOL Solvent	0.954	7.94	0.00088	100	100	0.24	31.0	33.2
Methoxytriglycol	1.050	8.74	0.00084	100	100	0.04	34.7	48.4
Ethoxytriglycol	1.025	8.53	0.00086	100	100	0.04	32.2	45.7
Hexyl CARBITOL Solvent	0.935	7.78	0.00084	3	56.30	0.03	29.2[(f)]	—
Butoxytriglycol	0.989	8.19	0.00085	100	100	< 0.1	30.0	32.2

(a) Tag Closed Cup unless otherwise noted
(b) All solutions are percent by volume
(c) Sets to glass below this temperature
(d) Pensky-Martens Closed Cup
(e) Decomposes at 760 mm Hg, boiling point extrapolated
(f) at 2°C
(g) 1% solution

(continued)

Table 11.67: (continued)

Constant Boiling Azeotropic Mixtures of Glycol Ethers and Other Solvents

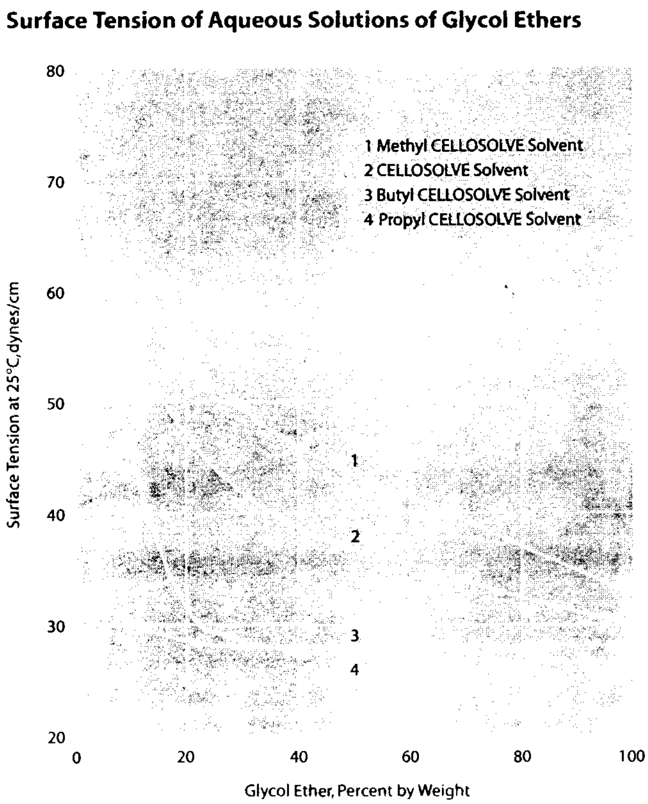
	Components	
Solvent	**Specific Gravity at 20/20°C**	**Boiling Point at 760 mm Hg, °C**
Methyl CELLOSOLVE Solvent	0.966	124.5
Toluene	0.868	10.6
Methyl CELLOSOLVE Solvent	0.966	124.5
Water	1.000	100.0
Methyl CARBITOL Solvent	1.023	194.0
Ethylene Glycol	1.115	197.6
CELLOSOLVE Solvent	0.931	135.6
Butyl Acetate	0.88	126.0
CELLOSOLVE Solvent	0.931	135.6
Toluene	0.868	110.6
CELLOSOLVE Solvent	0.931	135.6
Water	1.000	100.0
CARBITOL Solvent	0.991	202.7
Ethylene Glycol	1.115	197.6
Propyl CELLOSOLVE Solvent	0.913	150.1
Water	1.000	100.0
Butyl CELLOSOLVE Solvent	0.902	171.2
Water	1.000	100.0
Butyl CARBITOL Solvent	0.954	230.6
Ethylene Glycol	1.115	197.6
Hexyl CELLOSOLVE Solvent	0.889	208.1
Water	1.000	100.0
Hexyl CARBITOL Solvent	0.935	259.1
Water	1.000	100.0

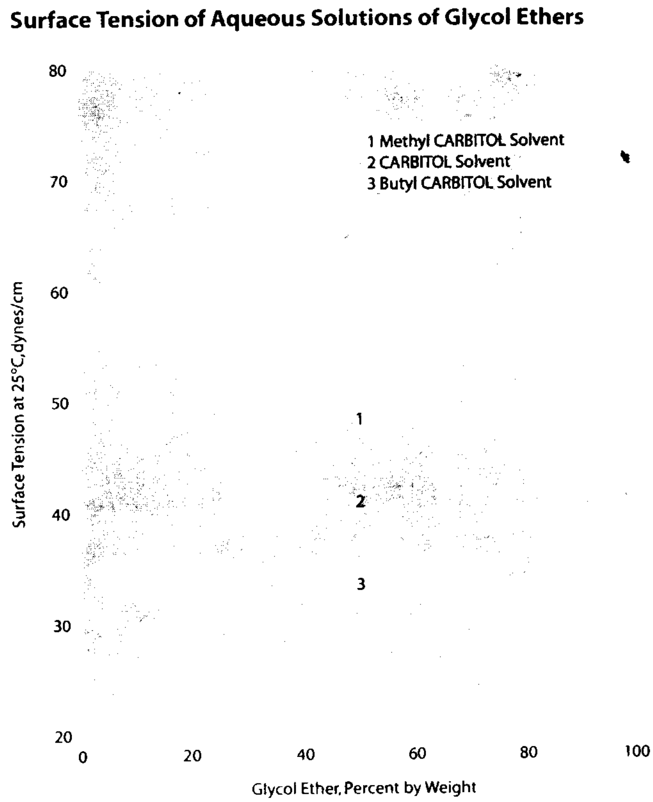
	Azeotrope					
		Composition, % by Wt, at 20°C				
Solvent	**Boiling Point at 760 mm Hg, °C**	**in Azeotrope**	**in Upper Layer**	**in Lower Layer**	**Relative Volume of Layers at 20°C**	**Specific Gravity at 20/20°C of Azeotrope Layer**
Methyl CELLOSOLVE Solvent		25	—	—	—	
Toluene	105.9	75	—	—	—	0.887
Methyl CELLOSOLVE Solvent		15	—	—	—	
Water	99.9	85	—	—	—	—
Methyl CARBITOL Solvent		70	—	—	—	
Ethylene Glycol	192	30	—	—	—	1.051
CELLOSOLVE Solvent		35.7	—	—	—	
Butyl Acetate	125.8	64.3	—	—	—	0.896
CELLOSOLVE Solvent		10.0	—	—	—	
Toluene	110.0	90.0	—	—	—	0.874
CELLOSOLVE Solvent		28.8	—	—	—	
Water	99.4	71.2	—	—	—	1.003
CARBITOL Solvent		54.5	—	—	—	
Ethylene Glycol	192	45.5	—	—	—	—
Propyl CELLOSOLVE Solvent		30	—	—	—	
Water	98.8	70	—	—	—	—
Butyl CELLOSOLVE Solvent		20.8	57	10	—	
Water	98.8[(a)]	79.2	43	90	—	0.989[(b)]
Butyl CARBITOL Solvent		27.5	—	—	—	
Ethylene Glycol	196.2	72.5	—	—	—	1.074
Hexyl CELLOSOLVE Solvent		9	81.2	1.0	U 11	U 0.915
Water	99.7	91	18.8	99.0	L 89	L 1.000
Hexyl CARBITOL Solvent		2	43.7	1.7	U 0.5	U 0.982
Water	100.0	98	56.3	98.3	L 99.5	1.000

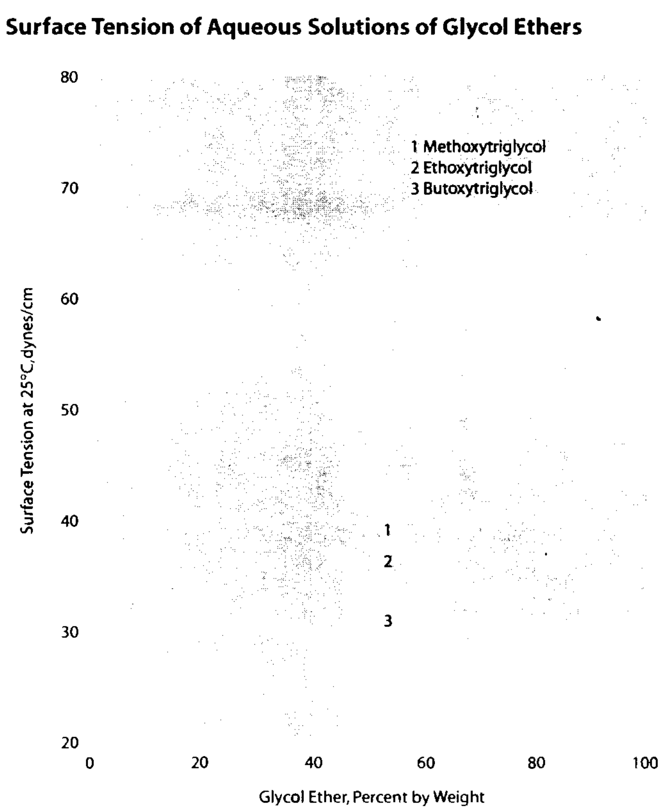
(a) Heterogeneous at this boiling point (b) Homogeneous at 20°C

(continued)

Table 11.67: (continued)







(continued)

Table 11.67: (continued)

Relative Evaporation of Glycol Ethers

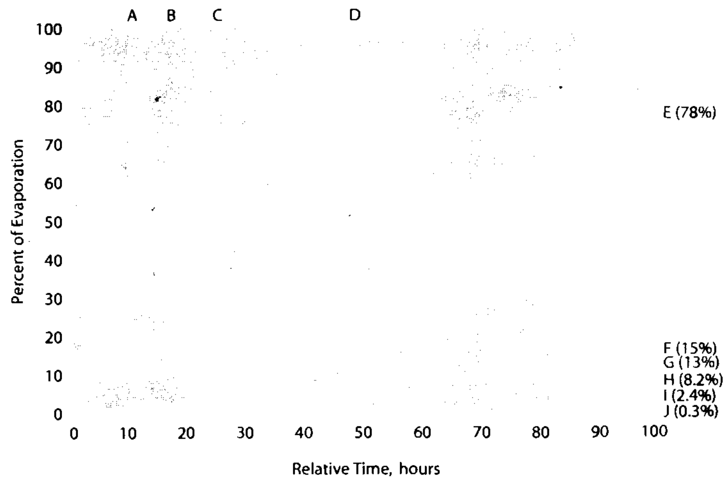
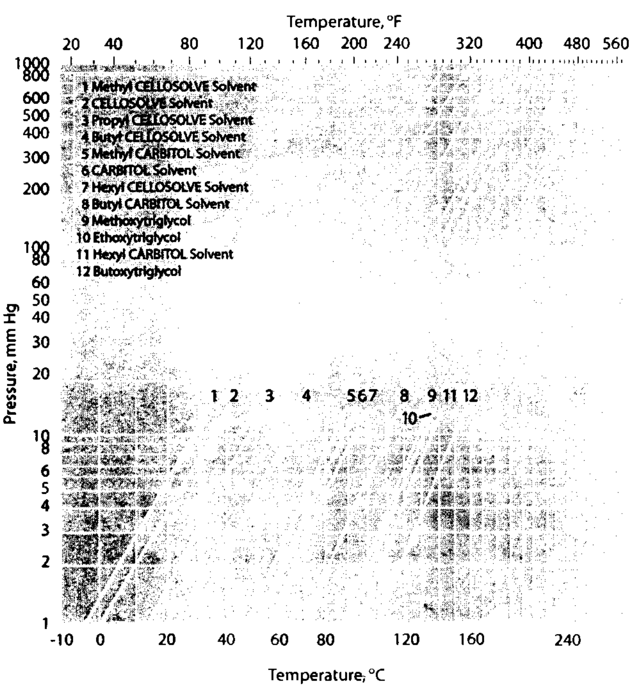


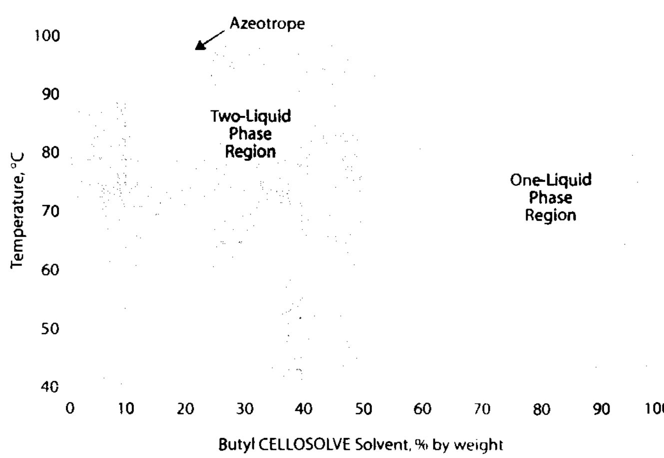
Chart Key:

- A Butyl Acetate
- B Methyl CELLOSOLVE Solvent
- C CELLOSOLVE Solvent
- D Propyl CELLOSOLVE Solvent
- E Butyl CELLOSOLVE Solvent
- F Methyl CARBITOL Solvent
- G CARBITOL Solvent
- H Hexyl CELLOSOLVE Solvent
- I Butyl CARBITOL Solvent
- J Hexyl CARBITOL Solvent

Vapor Pressures of Glycol Ethers



Mutual Solubility of Butyl CELLOSOLVE® Solvent/Water vs Temperature



(continued)

Table 11.67: (continued)

Ecological Effects of Glycol Ethers

Glycol Ether	Theoretical Oxygen Demand[a], mg O_2/mg		Biodegradation[b] %			Bacterial[c] IC_{50} mg/L	Fathead Minnow[d,e] LC_{50} mg/L	*Daphnia Magna*[d,e] LC_{50} mg/L
	Measured	Calculated	Day 5	Day 10	Day 20			
Methyl CELLOSOLVE Solvent	1.64	1.68	30	62	88	> 10,000	> 5,400	> 10,000
Methyl CARBITOL Solvent	—	1.34	5	73	100	> 5,000	> 10,000	> 10,000
Methoxytriglycol	—	1.75	29	33	71	> 5,000	> 10,000	> 10,000
CELLOSOLVE Solvent	1.98	1.86	36	88	100	> 10,000	> 10,000	> 10,000
CARBITOL Solvent	1.74	1.90	17	71	87	> 5,000	> 10,000	> 10,000
Ethoxytriglycol	—	1.89	8	47	71	> 10,000	> 10,000	> 10,000
Propyl CELLOSOLVE Solvent	1.94	2.15	13	66	100	> 1,000	> 5,000	> 5,000
Butyl CELLOSOLVE Solvent	2.25	2.30	26	74	88	> 5,000	1,700	> 1,000
Butyl CARBITOL Solvent	2.05	2.17	22	64	77	> 1,000	2,500	> 1,000
Butoxytriglycol	—	2.10	< 5	5	47	> 5,000	2,400	2,210
Hexyl CELLOSOLVE Solvent	1.89	2.52	72	93	100	770	140	305
Hexyl CARBITOL Solvent	—	2.36	23	69	80	> 1,000	220	433

(a) Calculated theoretical oxygen demand (THOD) based on complete oxidation of the chemical to carbon dioxide and water. Measured value determined by chemical oxygen demand procedure published in *Standard Methods for the Examination of Water and Wastewater,* 18th ed., Am. Public Health Assoc., Washington, D.C. (1992)

(b) Based on biooxidation measured in the dilution bottle biochemical oxygen demand (BOD) test published in Standard Methods. Biooxidation is the percentage ratio of BOD to THOD [(BOD/ThOD)*100%]. Nonacclimated domestic sewage microorganisms were used as seed in the tests.

(c) Determined by turbidity/growth procedures where the median inhibition concentration (IC_{50}) is measured after 16 hours of incubation with sewage microorganisms.

(d,e) EPA/ASTM bioassay procedures were followed in obtaining these values. Ten test organisms were used per test concentrations.

POLYETHYLENE GLYCOLS

Table 11.68: Ashland Polyethylene Glycols *(69)*

Soluble in water with resultant solutions being transparent, ASHLAND® polyethylene glycols are designated by numbers which approximate their average molecular weight. Intermediate combinations may be obtained by blending various grades.

Polyethylene Glycols 200, 300, 400 and 600
Water-soluble viscous liquids at normal temperatures, polyethylene glycols are also soluble in ketones, alcohols, glycol ethers, esters and aromatic hydrocarbons. Their viscosities and freezing points increase as the molecular weight increases. Used as paper softeners, in tire air bag lubricants and lotions. Fatty acid esters prove useful as emulsifiers, dispersants and lubricants.

Polyethylene Glycols 1000, 1450, 3350, 4600 and 8000
From semi-solid to the higher molecular weight hard waxy white solids, this group of polyethylene glycols finds use as mold lubricants and mold release agents in the rubber industry. Used in preparation of ointments, cosmetic creams and lotions, metal polishes, shoe polishes, abrasives and adhesives.

ASHLAND® polypropylene glycols have average molecular weights ranging from 400 to 4,000, and encompass a wide range of physical and chemical properties. They are used in cosmetic formulations, brake fluids, lubricating oils and greases, and rubber processing.

Product	Specific Gravity 20°/20°C	Lb/Gal at 20°C	Average Molecular Weight	Freezing Range °C	Flash Point °F PM*	Viscosity Centistokes at 210°F
Polyethylene Glycol 200	1.127	9.38	200	Supercools	>300	4.3
Polyethylene Glycol 300	1.127	9.38	300	−15 to −8	>350	5.8
Polyethylene Glycol 400	1.128	9.39	400	4-8	>350	7.3
Polyethylene Glycol 600	1.128	9.40	600	20-25	>350	10.5
Polyethylene Glycol 1000	1.101 (55/20)	9.16 (55°C)	1000	37-40	>350	17.4
Polyethylene Glycol 1450	1.102 (55/20)	9.17 (55°C)	1450	43-46	>350	25-32
Polyethylene Glycol 3350	1.1072 (a)	8.94 (80°C)	3350	54-58	>350	75-110
Polyethylene Glycol 4600	1.073 (a)	8.95 (80°C)	4600	57-61	>350	160-230
Polyethylene Glycol 8000	1.075 (a)	8.96 (80°C)	8000	60-63	>350	700-900
Polyethylene Glycol 20000	1.065 (80/20)	8.67 (130°C)	17500	50-55	>350	14,500

*Pensky-Martens
(a) Density @ 80°C

Table 11.69: BASF Pluracol E Polyethylene Glycols *(47)*

Product	Average Molecular Weight	Form	Viscosity at 99° C, CS	Flash Pt. °C[b]	Pour Point °C
E200	200	Liquid	4.4	182	−65
E300	300	Liquid	5.9	210	−13
E400, E400 NF	400	Liquid	7.4	238	5
E600, E600 NF	600	Liquid	10.8	249	20
E1000	1000	Solid	17.5	255	38[a]
E1450, E1450 NF	1450	Solid	28.5	255	45[a]
E2000	2000	Solid	43.5	>260	52[a]
E4000	4000	Solid	134.0	>260	59[a]
E4500	4500	Solid	170.0	>260	60[a]
E8000	8000	Solid	750.0	>260	61[a]

[a] Melting point [b] Cleveland open cup [c] Pensky-Martens closed cup [d] Flash points measured by the closed cup method, ASTM D-56

Table 11.70: CARBOWAX Polyethylene Glycols *(19)*

Typical Physical Properties of CARBOWAX Polyethylene Glycols and Methoxypolyethylene Glycols

Product	Range of Average Molecular Weight	Liquid Density, g/cc 20°C	Liquid Density, g/cc 60°C	Liquid Density, g/cc 80°C	Melting or Freezing Range, °C	Solubility in Water at 20°C, % by wt	Viscosity at 210°F, cSt	Average Number of Repeating Oxyethylene Units
CARBOWAX® Polyethylene Glycol								
200	190 to 210	1.1238	1.0921	1.0763	(f)	Complete	4.3	4.1
300	285 to 315	1.1249	1.0927	1.0766	-15 to -8	Complete	5.8	6.4
400	380 to 420	1.1255	1.0931	1.0769	4 to 8	Complete	7.3	8.7
540 Blend (a)	468 to 534	(h)	1.0930	1.0765	38 to 41	73	15.1	(a)
600	570 to 630	1.1258	1.0931	1.0767	20 to 25	Complete	10.8	13.2
900	855 to 945	(h)	1.0926	1.0763	32 to 36	86	15.3	20.0
1000	950 to 1050	(h)	1.0927	1.0765	37 to 40	80	17.2	22.3
1450	1305 to 1595	(h)	1.0919	1.0761	43 to 46	72	26.5	32.5
3350	3015 to 3685	(h)	1.0926	1.0769	54 to 58	67	90.8	75.7
4000	3600 to 4400	(h)	1.0926	1.0769	57 to 59	66	140.4	90.5
4600	4140 to 5060	(h)	1.0926	1.0764	57 to 61	65	183.9	104.1
8000	7000 to 9000	(h)	1.0852 (b)	1.0689 (d)	60 to 63	63	821.7	181.4
Compound 20M	17,500 (g)	(h)	1.0540 (c)	1.0392 (e)	61 to 65	65 (g)	18,655	2 moles 8000 joined with an epoxide
CARBOWAX® Methoxypolyethylene Glycol								
350	335 to 365	1.0894	1.0547	1.0373	-5 to 10	Complete	3.9	7.2
550	525 to 575	1.1039	1.0690	1.0515	15 to 25	Complete	6.5	11.8
750	715 to 785	(h)	1.0761	1.0595	27 to 32	Complete	10.3	16.3
2000	1800 to 2200	(h)	1.0871	1.0707	49 to 54	68	45.5	44.7
5000	4375 to 5625	(h)	1.0899	1.0742	57 to 63	64	319	112.9

Product	Surface Tension at 25°C, dynes/cm	Refractive Index, n_D20	Liquid Specific Heat at 25°C, cal/g/°C	Heat of Fusion, cal/g	Heat of Combustion (l) at 25°C, Btu/lb	CTFA (m)/INCI (n) Nomenclature
CARBOWAX® Polyethylene Glycol						
200	44.5	1.4597	0.51	(f)	10,510	PEG-4
300	44.5	1.4644	0.51	37	10,840	PEG-6
400	44.5	1.4667	0.51	36	11,010	PEG-8
540 Blend (a)	(h)	(h)	0.51 (k)	37	-11,070	PEG-6 (and) PEG-32
600	44.5	1.4688	0.51	35	-11,100	PEG-12
900	(h)	(h)	0.51 (k)	36	-11,210	PEG-18
1000	(h)	(h)	0.51 (k)	38	-11,240	PEG-20
1450	(h)	(h)	0.51 (k)	37	-11,300	PEG-32
3350	(h)	(h)	0.51 (k)	39	-11,380	PEG-75
4000	(h)	(h)	0.51 (k)	45	-11,390	PEG-90 (p)
4600	(h)	(h)	0.51 (k)	45	-11,390	PEG-100
8000	51.3 (i)	(h)	0.51 (k)	41	-11,410	PEG-180
Compound 20M	49.6 (i)	(h)	0.51 (k)	38	-11,430	–
CARBOWAX® Methoxypolyethylene Glycol						
350	40.5	1.4557	0.51	26	-11,340	PEG-6 Methyl Ether
550	40.7 (j)	1.4620	0.51	30	-11,400	Methoxy PEG-10
750	40.7 (j)	1.4572 (j)	0.51(k)	34	-11,350	Methoxy PEG-16
2000	(h)	(h)	0.51(k)	41	-11,390	Methoxy PEG-40
5000	(h)	(h)	0.51(k)	43	-11,410	Methoxy PEG-100

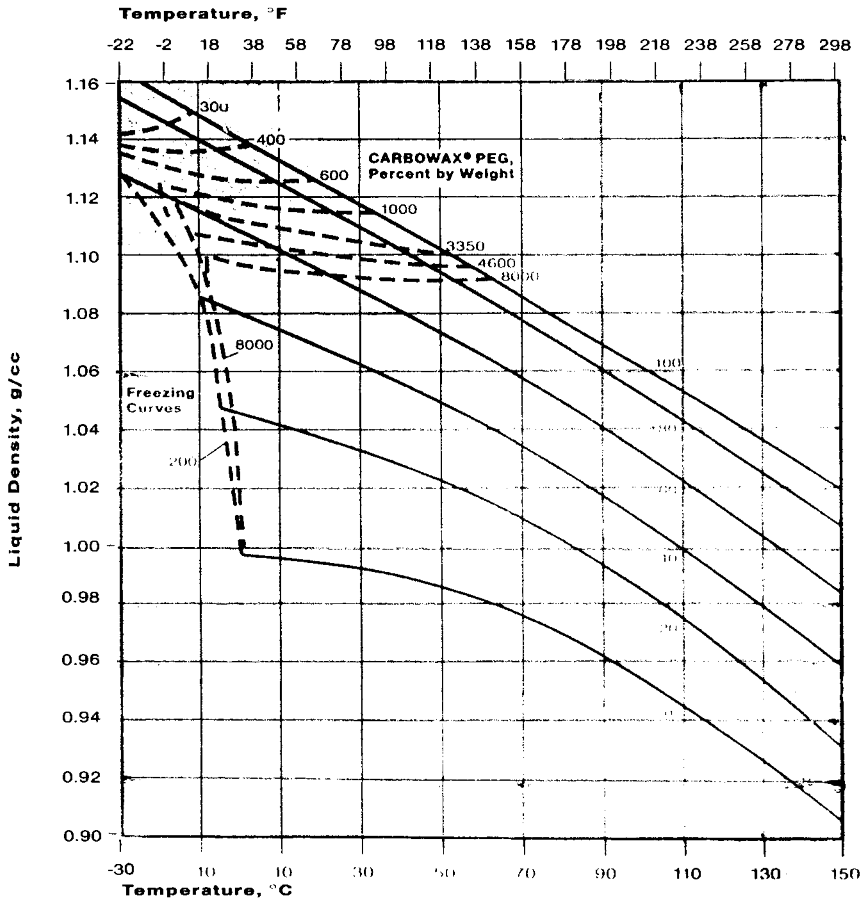
FOOTNOTES:

(a) A 41/59 wt % mixture of PEG-300 and PEG-1450
(b) At 70°C
(c) At 120°C
(d) At 90°C
(e) At 140°C
(f) Sets to glass below -65°C
(g) Approximate
(h) Solid at specified temperature
(i) 50% aqueous solution
(j) At 40°C
(k) Solid heat capacity
(l) Negative indicates heat evolved
(m) Cosmetics, Toiletries, and Fragrances Association
(n) International Nomenclature Cosmetic Ingredient
(p) Proposed CTFA/INCI Name

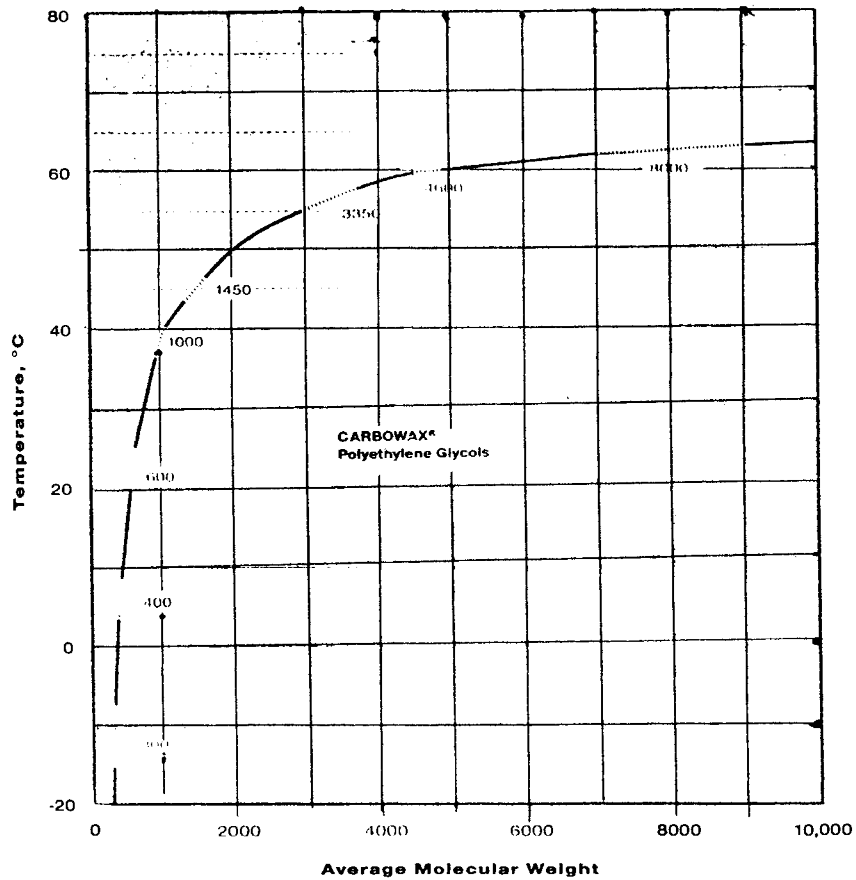
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Table 11.70: (continued)

Liquid Densities of Aqueous Solutions of Liquid and Solid CARBOWAX® Polyethylene Glycols



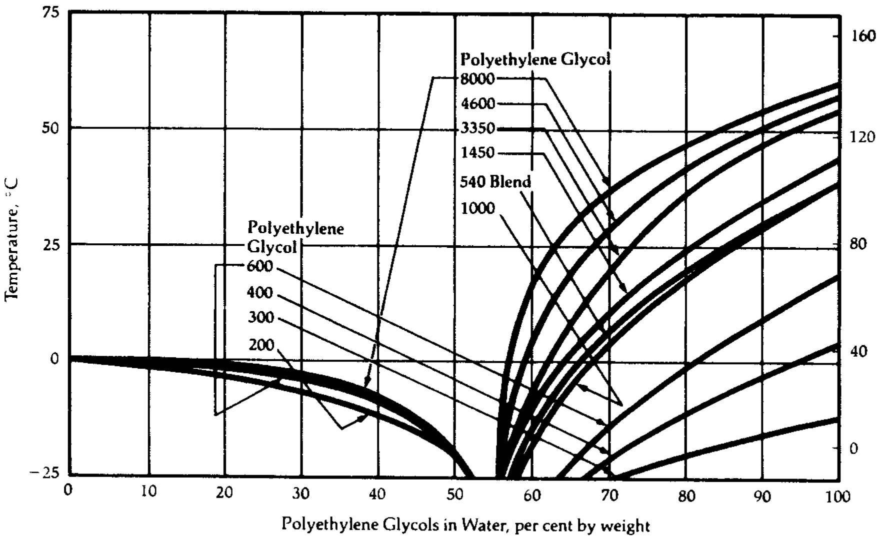
Melting/Freezing Range of CARBOWAX® Polyethylene Glycols vs. Molecular Weight



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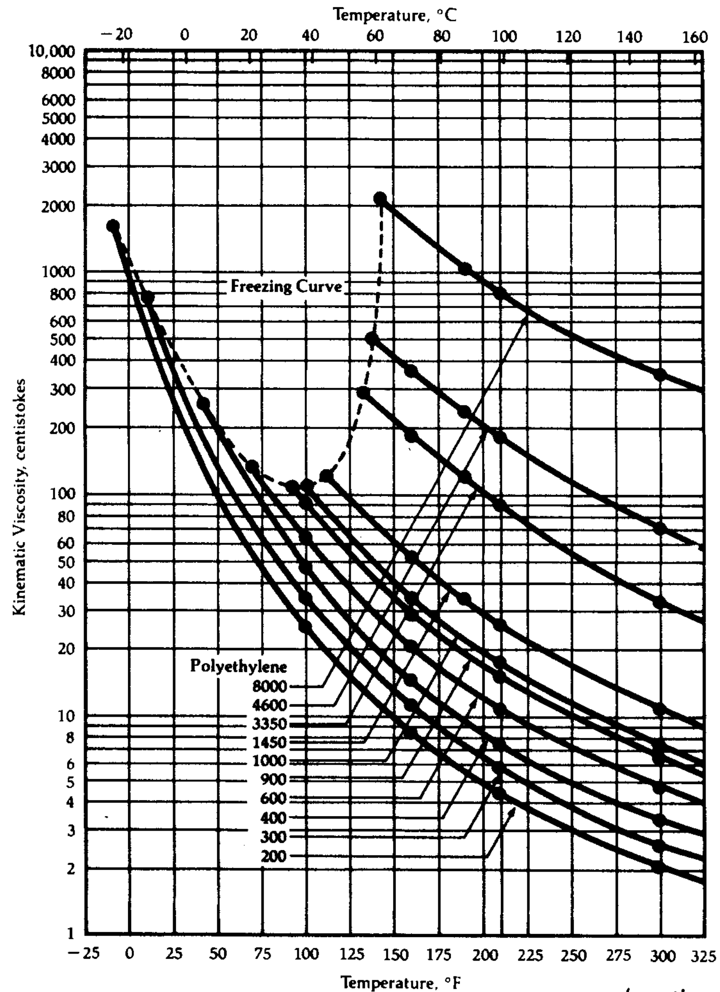
Table 11.70: (continued)

Freezing Points of Aqueous Solutions of Liquid and Solid CARBOWAX Polyethylene Glycols



Note: Below −23°C, all mixtures supercool and have no definite freezing point. In high concentrations of water, the curves for polyethylene glycols 300, 400, 1000, 540 Blend, 1450, and 3350 can be interpolated from the curves given.,

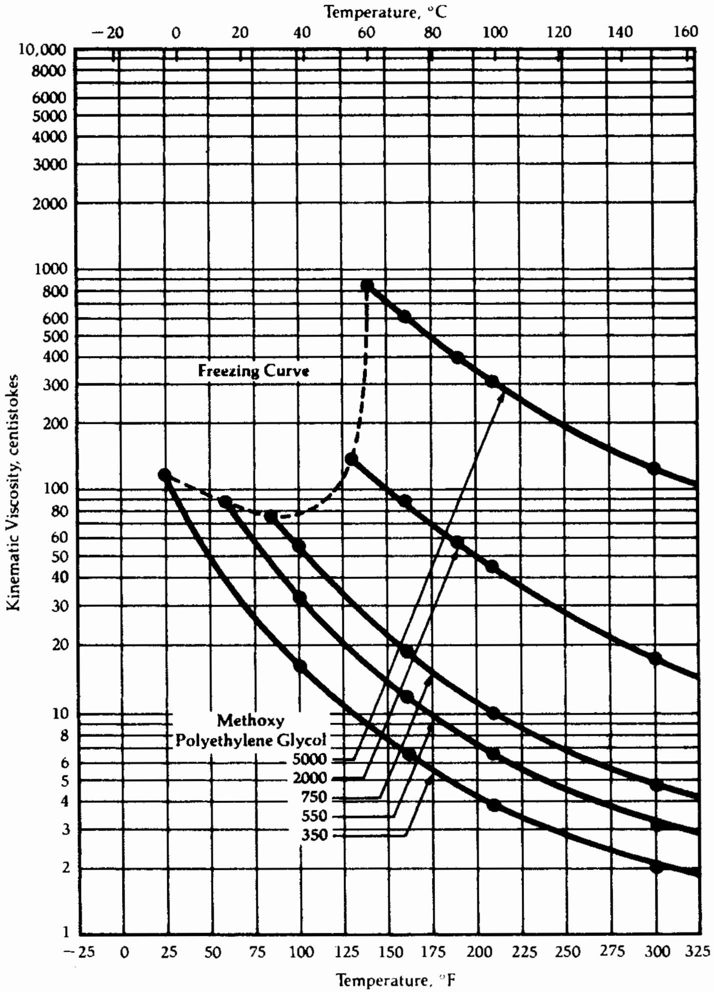
Kinematic Viscosity of CARBOWAX Polyethylene Glycols



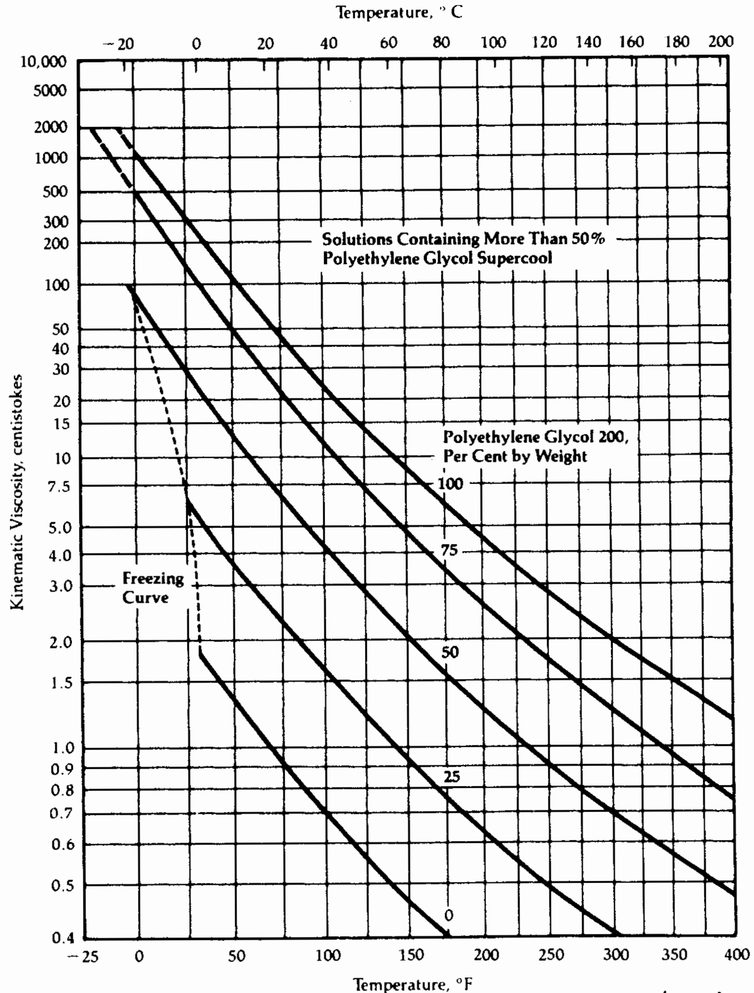
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Table 11.70: (continued)

Kinematic Viscosity of CARBOWAX Methoxypolyethylene Glycols



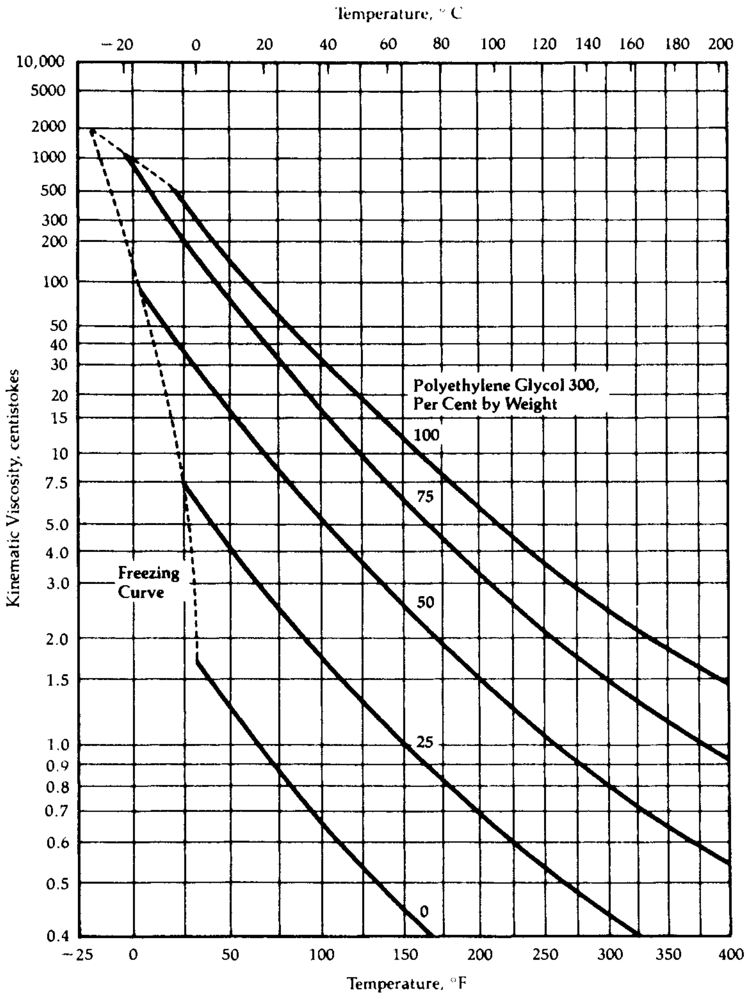
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 200



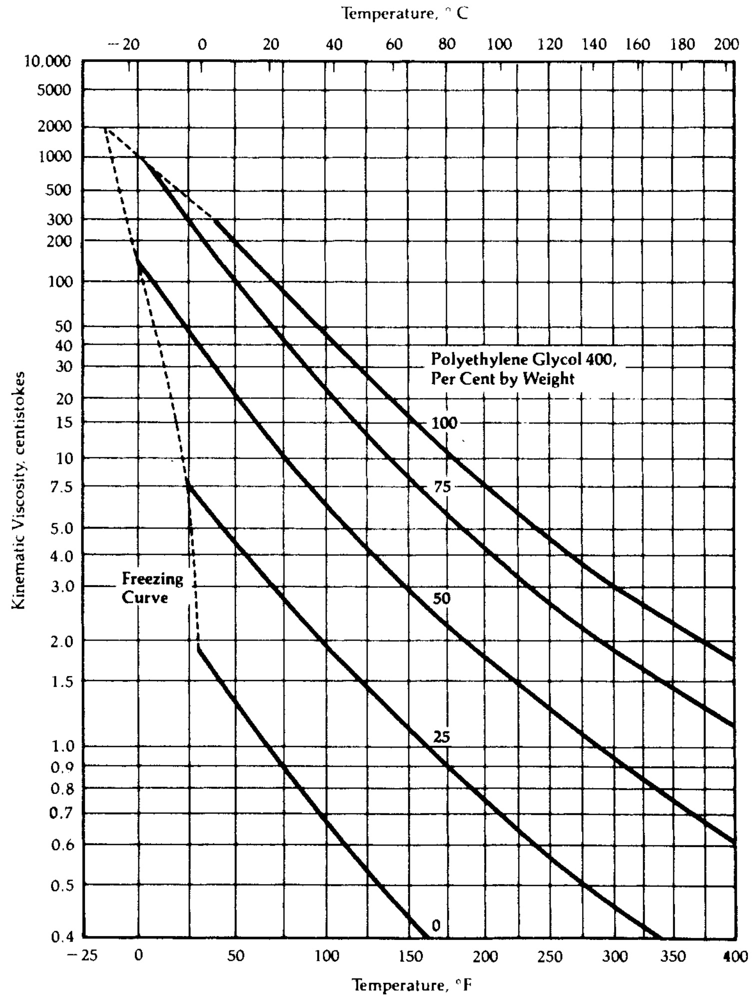
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Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 300



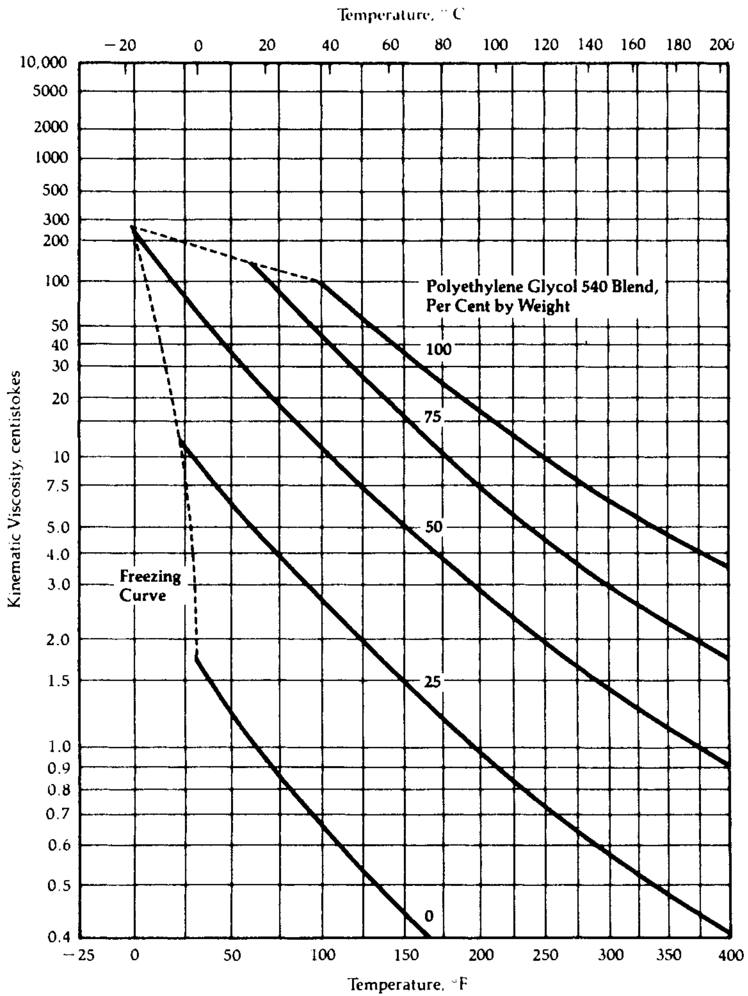
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 400



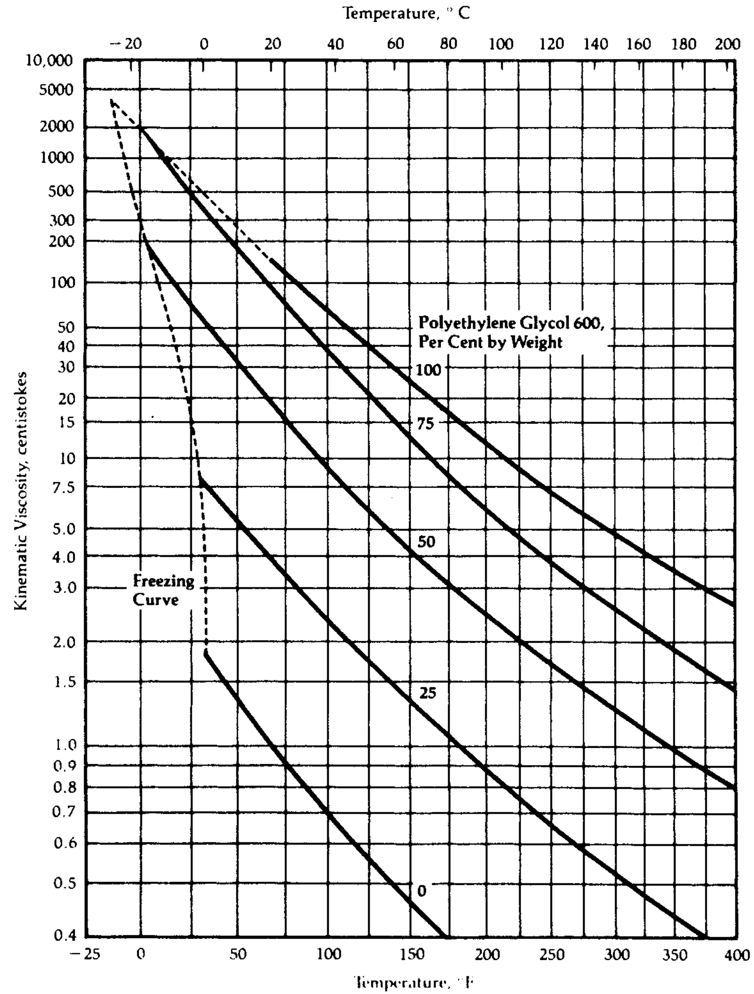
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Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 540 Blend



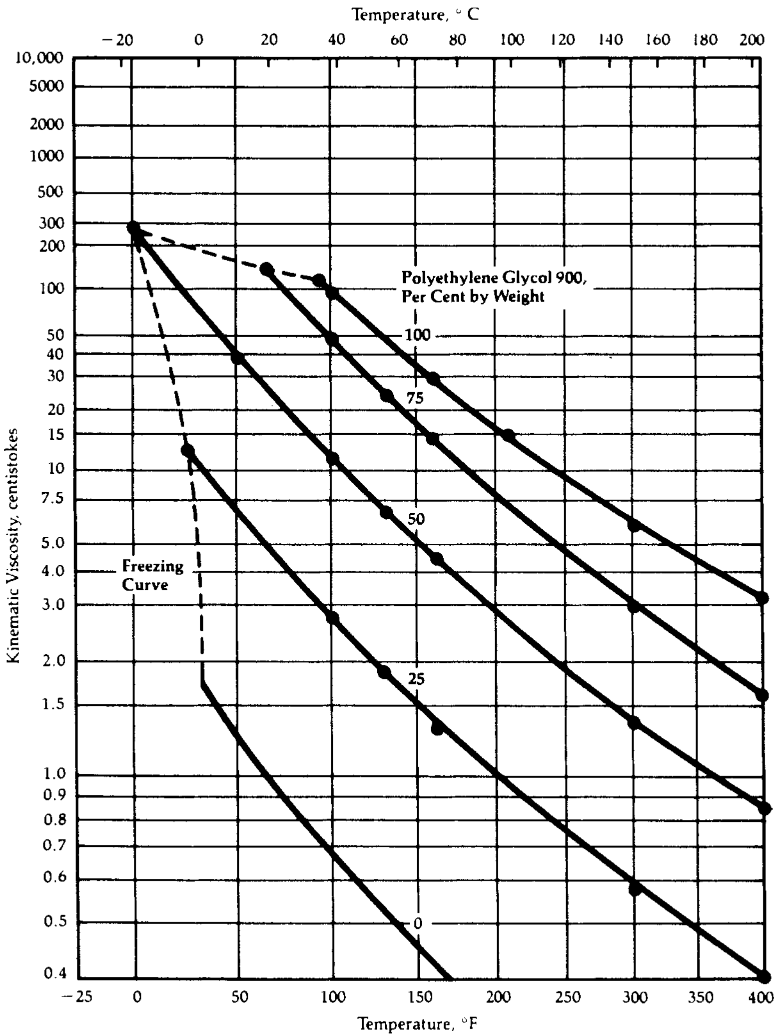
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 600



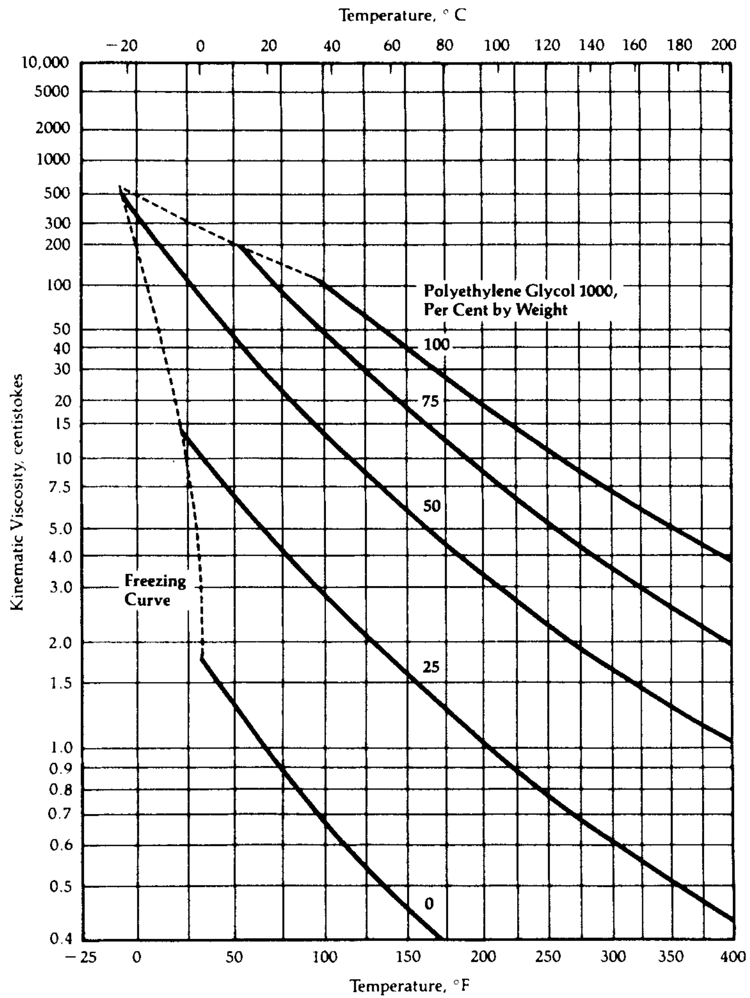
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Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 900



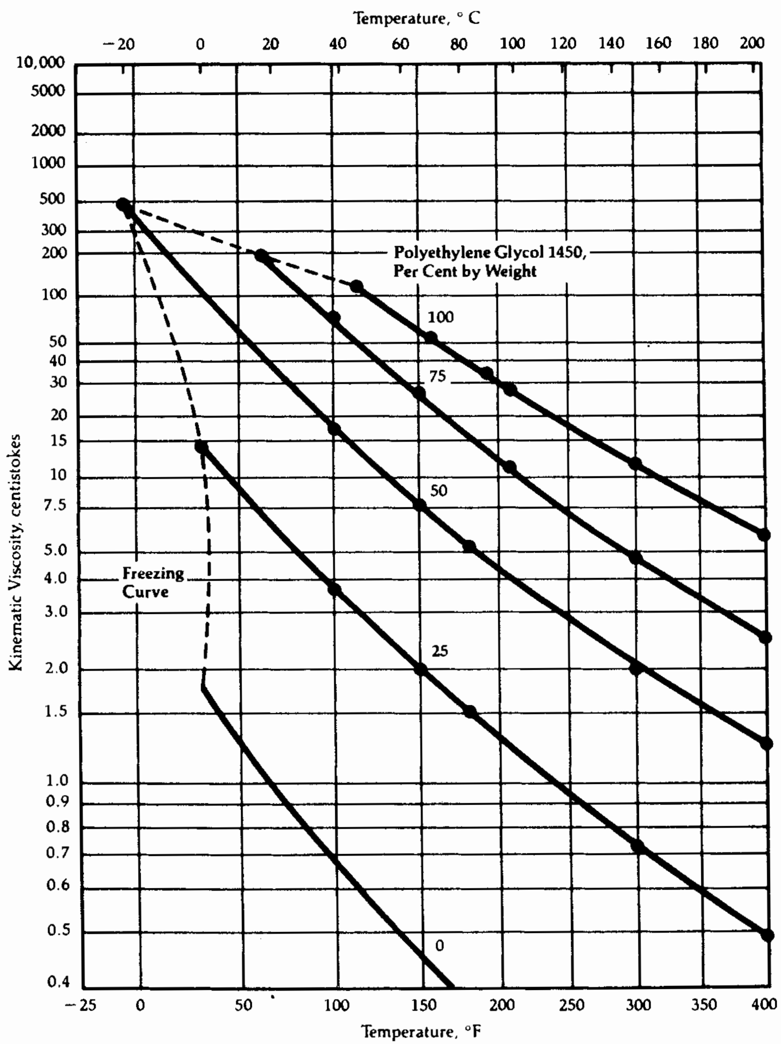
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 1000



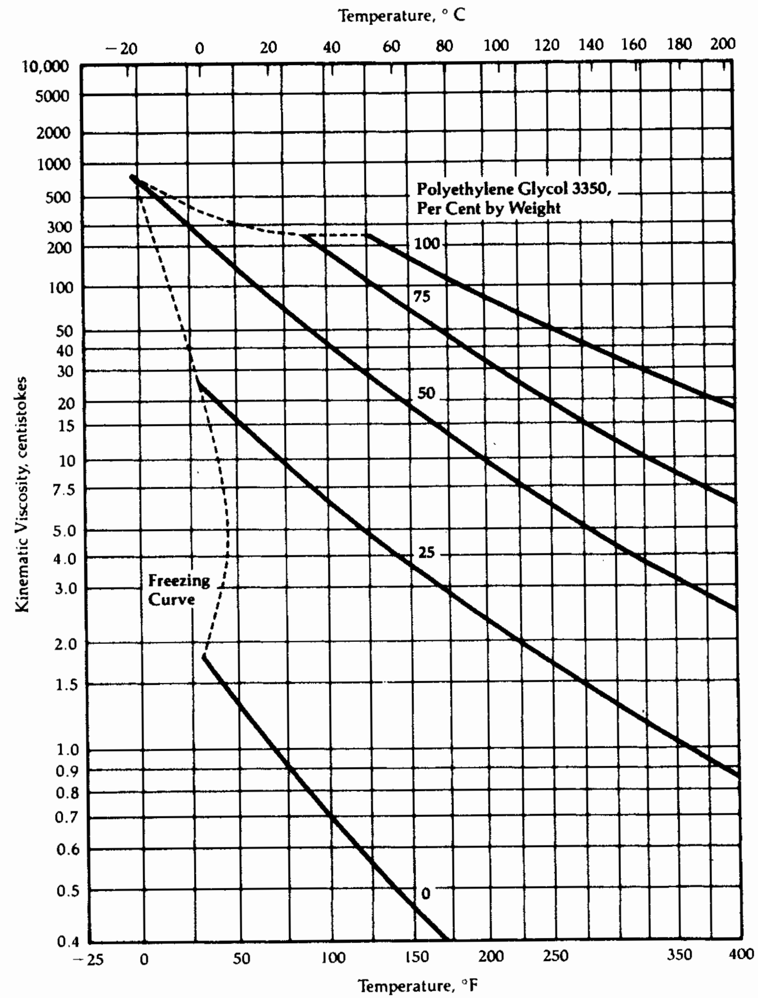
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Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 1450



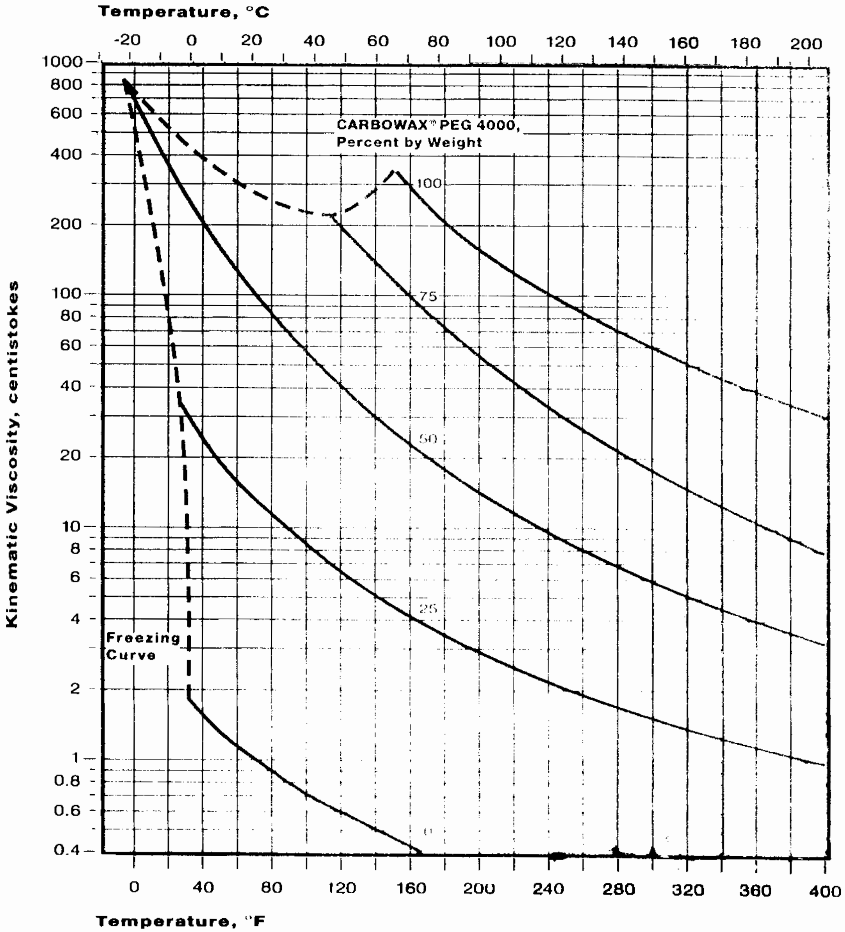
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 3350



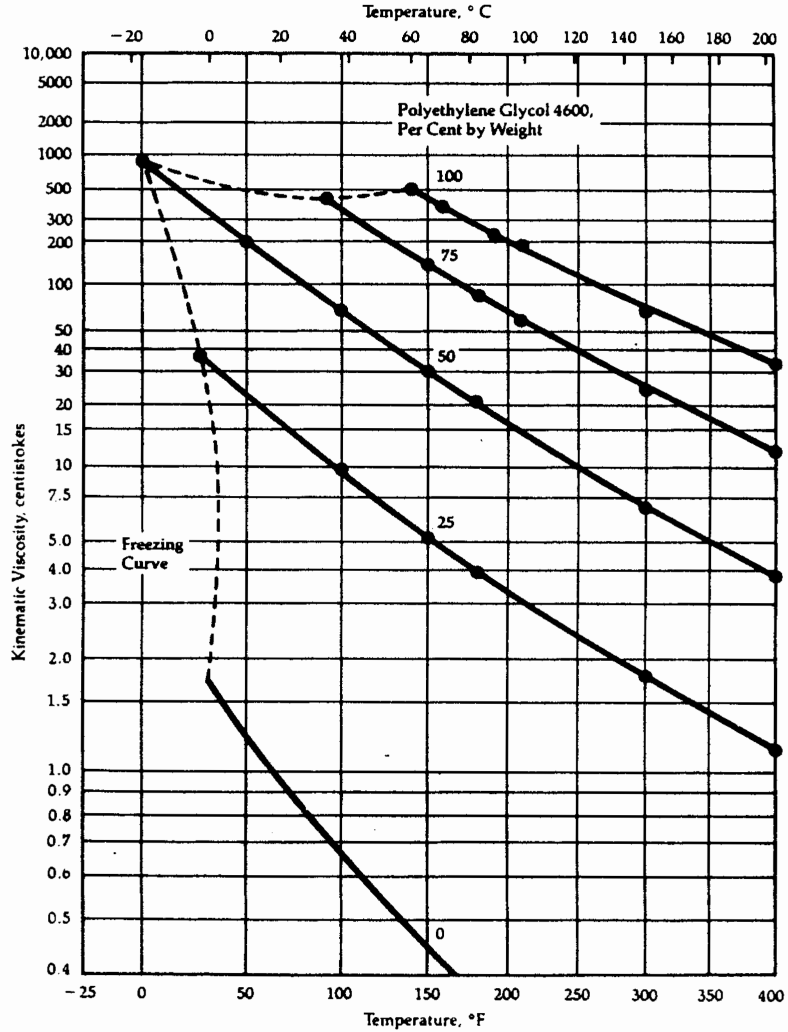
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Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 4000



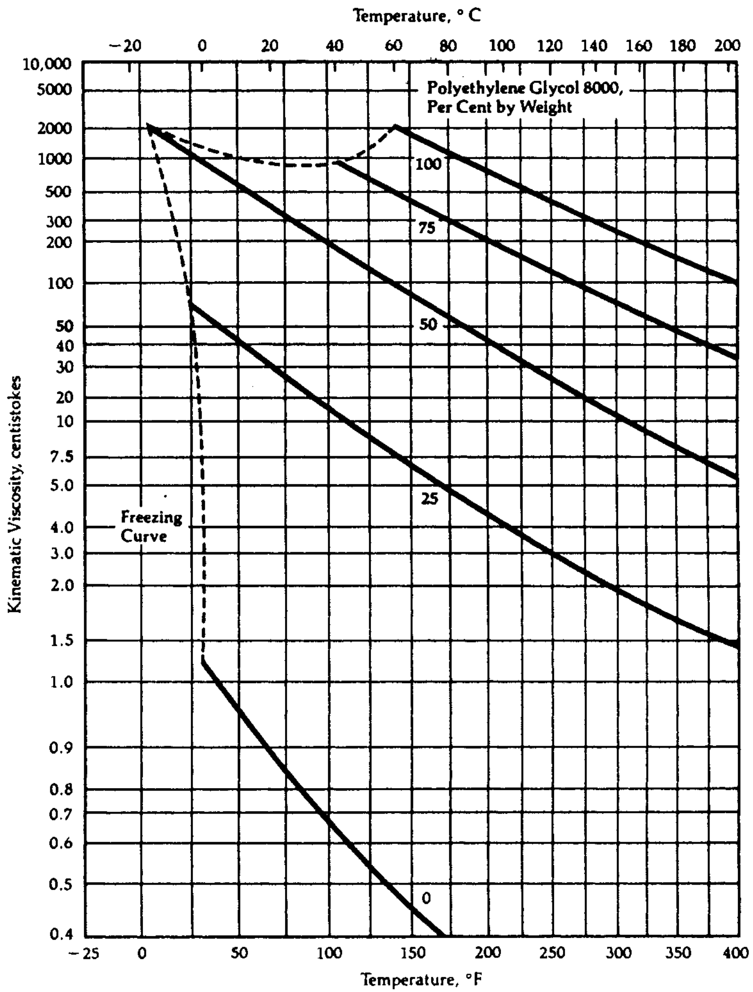
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 4600



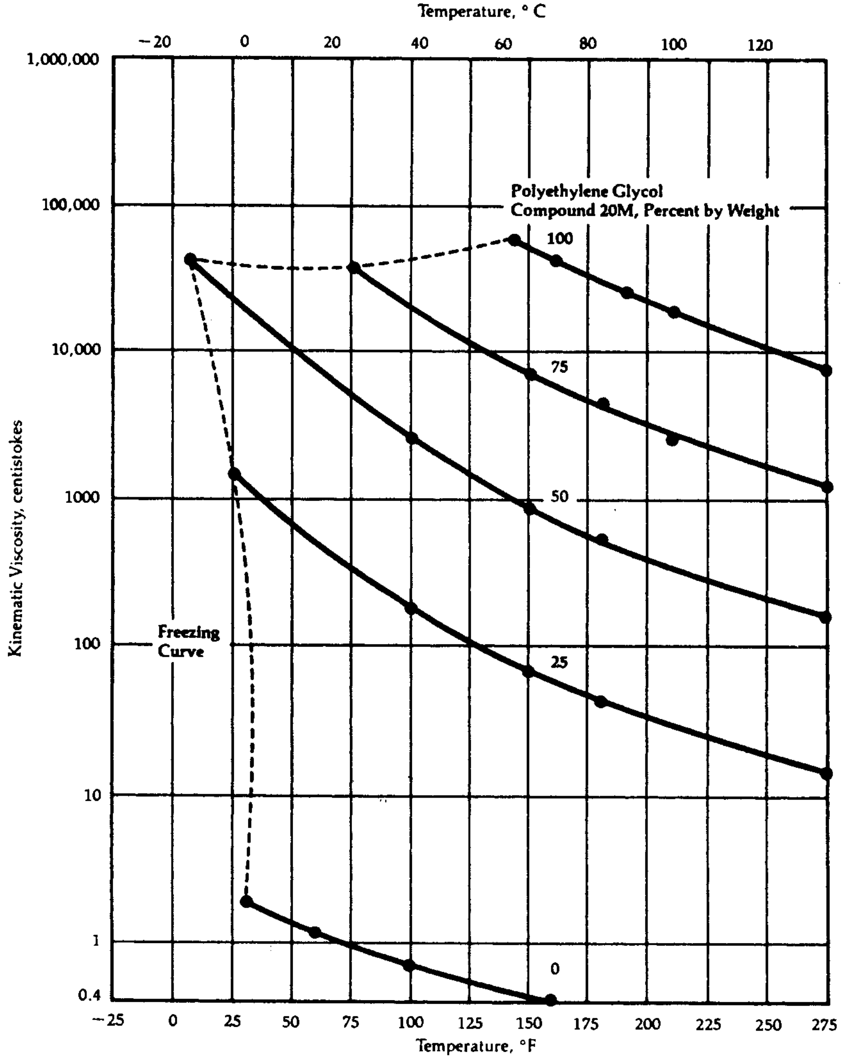
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Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol 8000



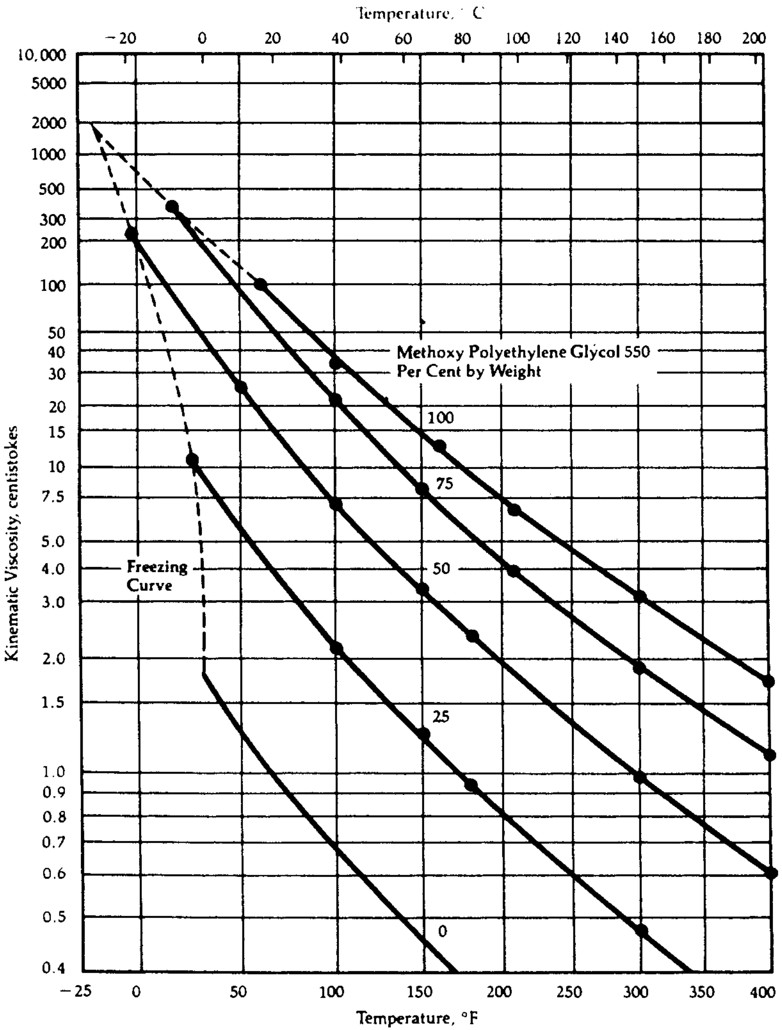
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Polyethylene Glycol Compound 20M



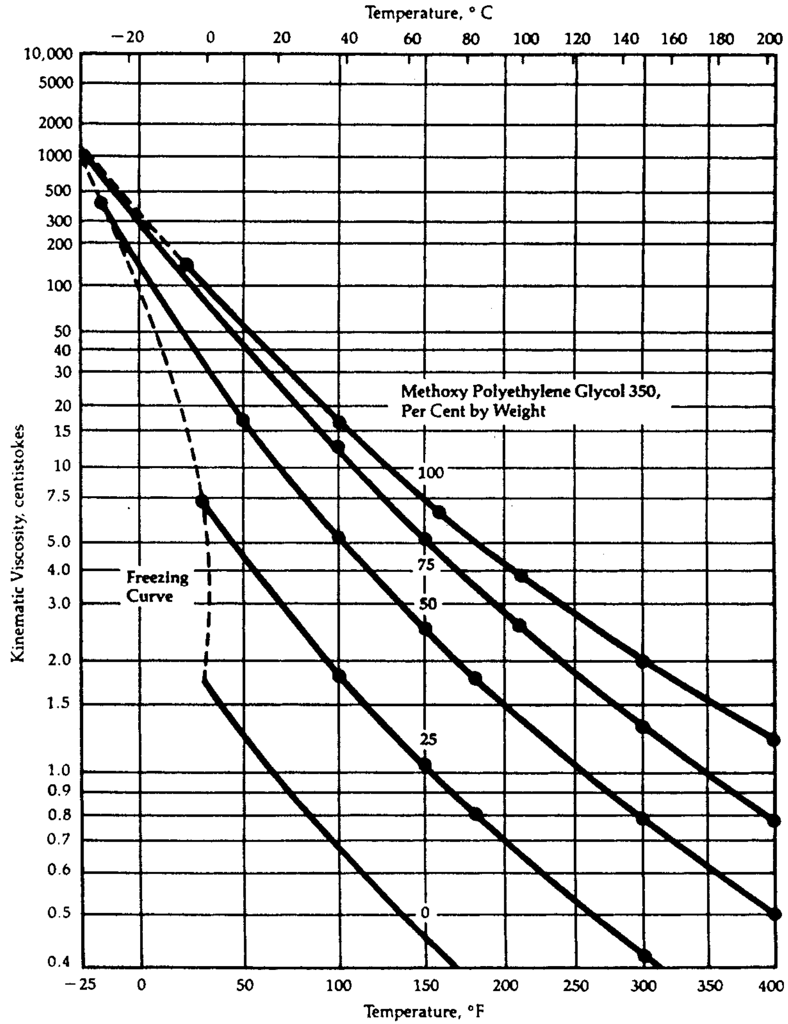
(continued)

Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Methoxypolyethylene Glycol 350



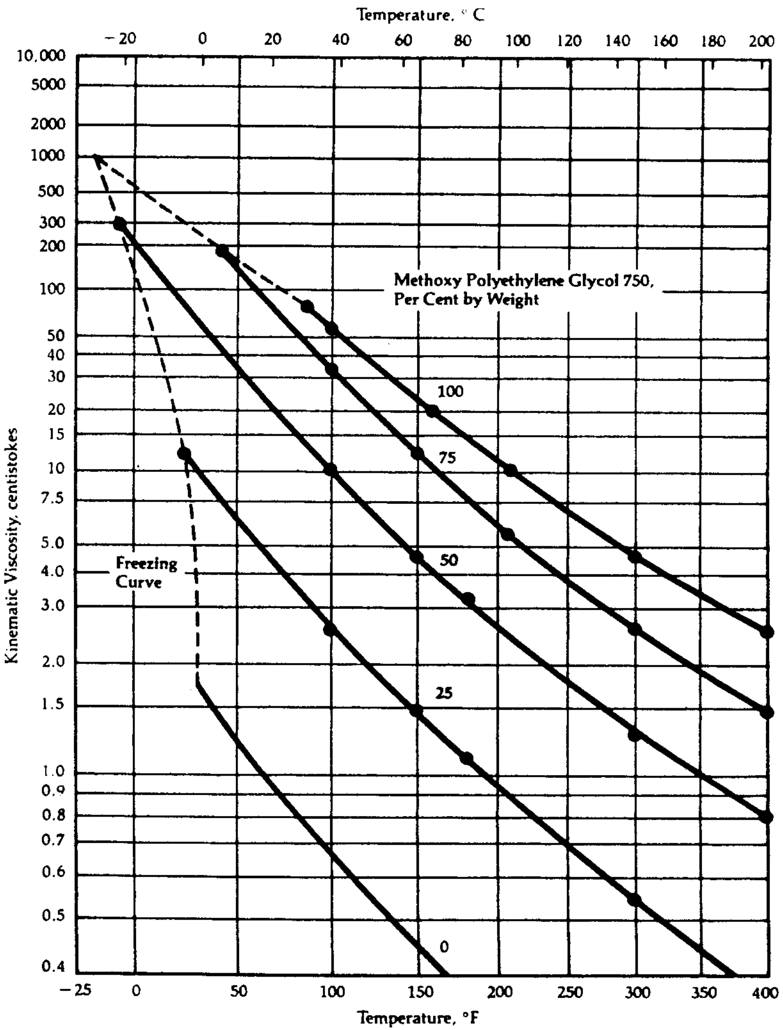
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Methoxypolyethylene Glycol 550



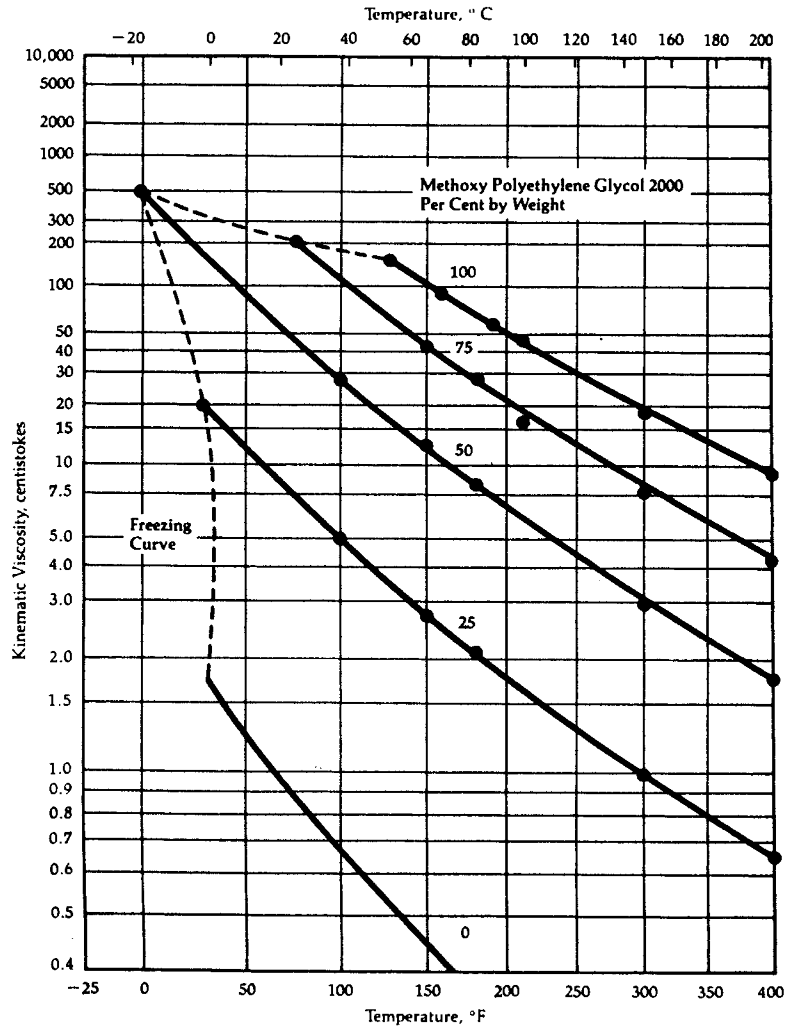
(continued)

Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Methoxypolyethylene Glycol 750



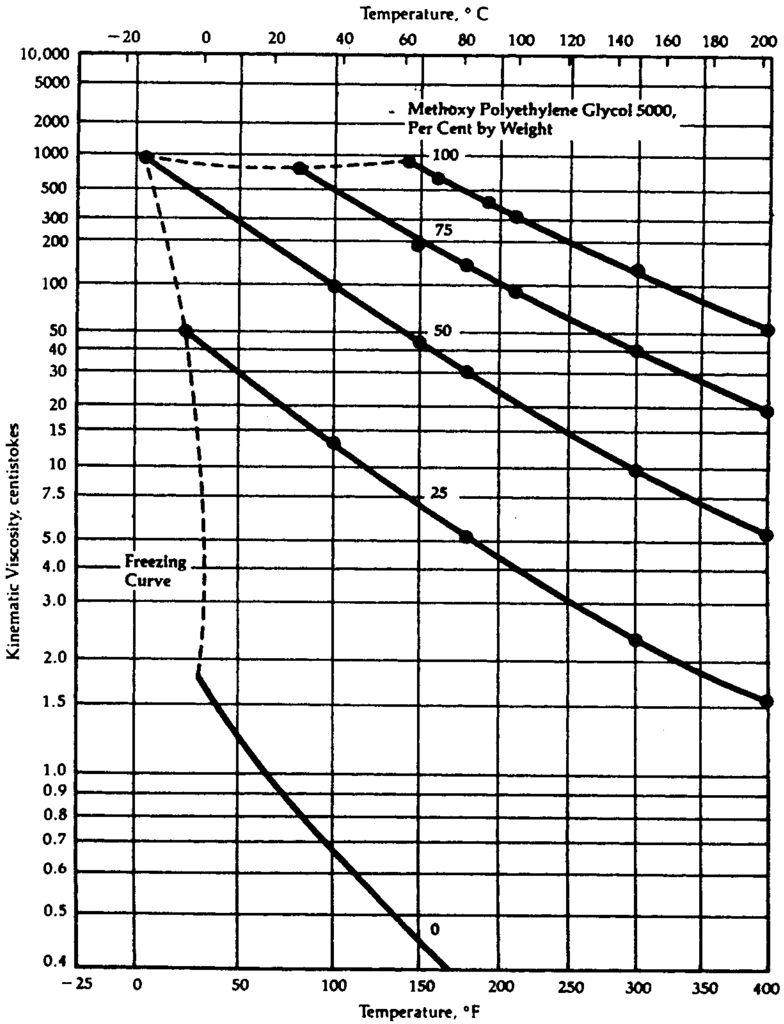
Kinematic Viscosity of Aqueous Solutions of CARBOWAX Methoxypolyethylene Glycol 2000



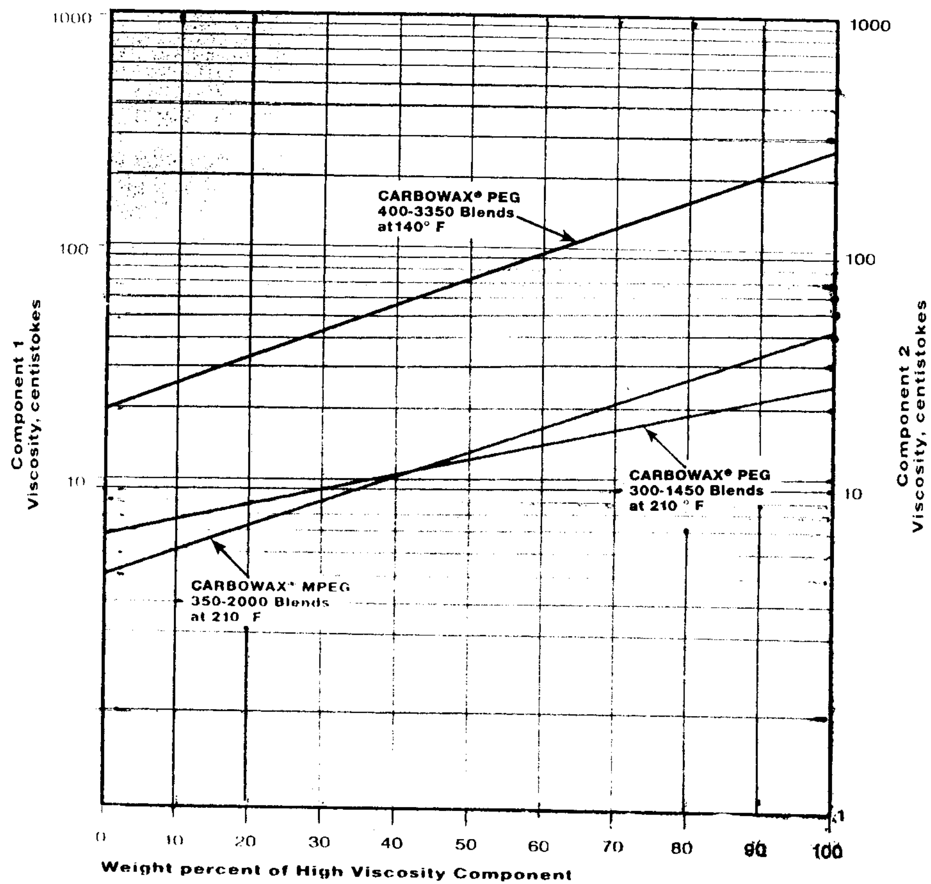
(continued)

Table 11.70: (continued)

Kinematic Viscosity of Aqueous Solutions of CARBOWAX Methoxypolyethylene Glycol 5000



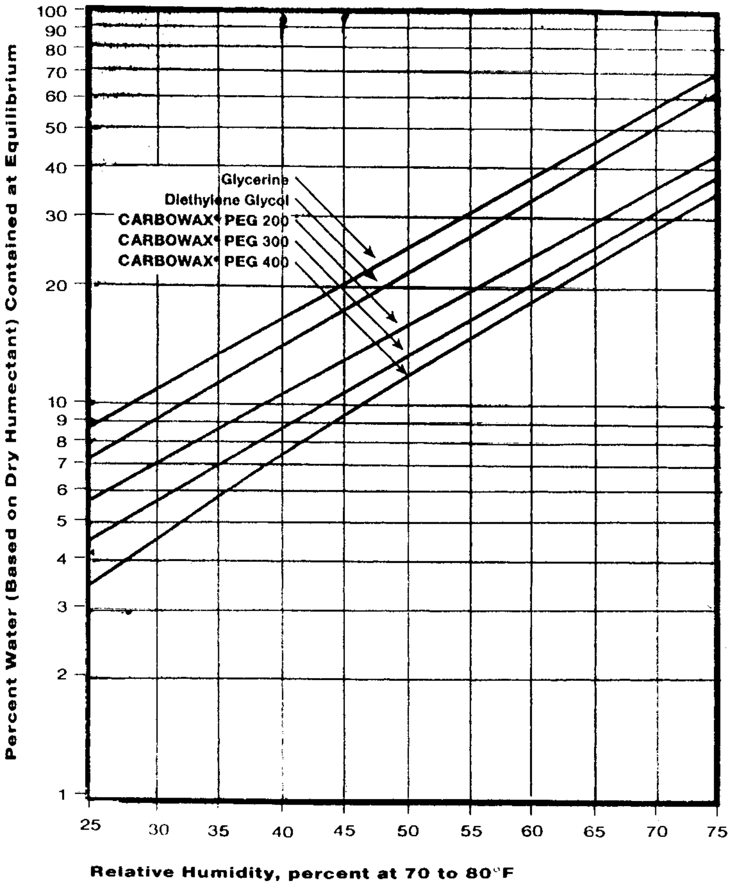
Kinematic Viscosity of Blends of CARBOWAX Polyethylene Glycols and Methoxypolyethylene Glycols



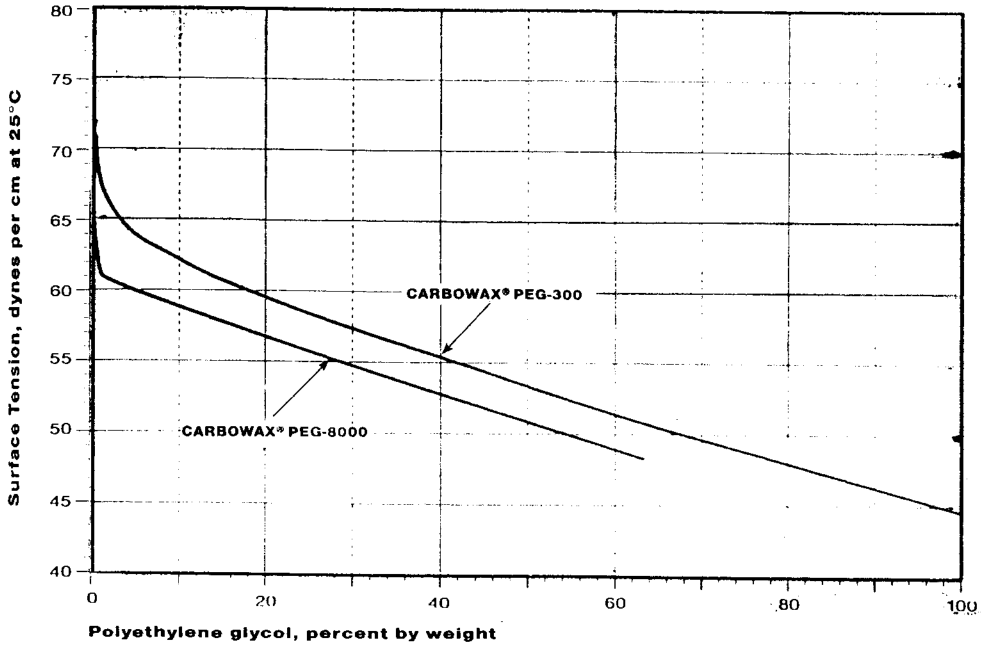
(continued)

Table 11.70: (continued)

Hygroscopicity of Liquid CARBOWAX Polyethylene Glycols at Various Relative Humidities



Surface Tensions of Aqueous Solutions of CARBOWAX Polyethylene Glycols at 25°C

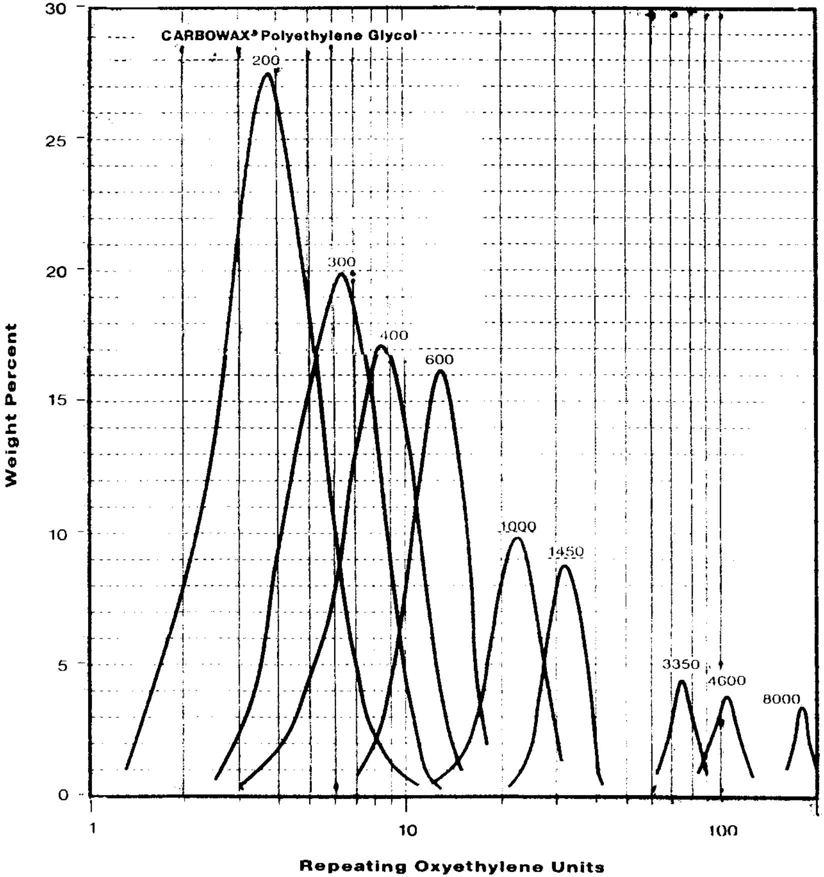


Note: These curves are valid to ± 1 dyne per cm. Surface tension for CARBOWAX® Polyethylene Glycol 400 to 4600 lie between the curves shown.

(continued)

Table 11.70: (continued)

Molecular Weight Distributions of CARBOWAX Polyethylene Glycols



Note: The curves for CARBOWAX® PEG 200, 300, 400, 600, 1000 and 1450 were determined by liquid chromatography. The curves for CARBOWAX® PEG 3350, 4600 and 8000 were determined by gel permeation chromatography.

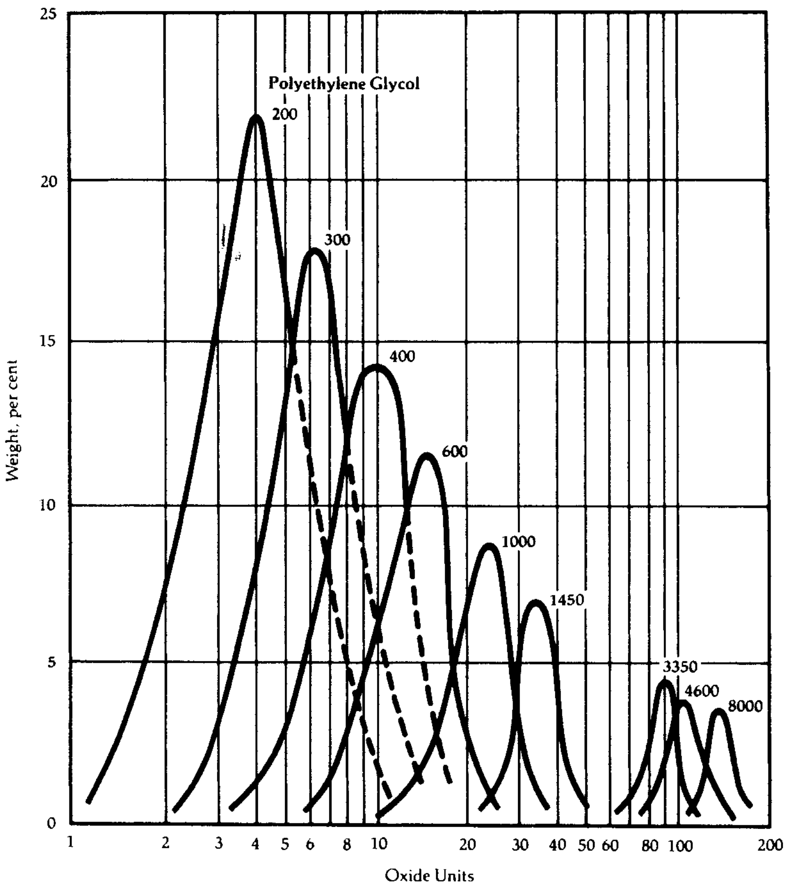
Effect of Molecular Weight on Physical Properties

Avg MW Range	Solubility	Hygroscopicity	Vapor Pressure	Melting or Freezing Range	Viscosity
200	HIGHER	HIGHER	HIGHER	lower	lower
300					
400					
600					
900					
1000					
1450					
3350					
4600					
8000	lower	lower	lower	HIGHER	HIGHER

(continued)

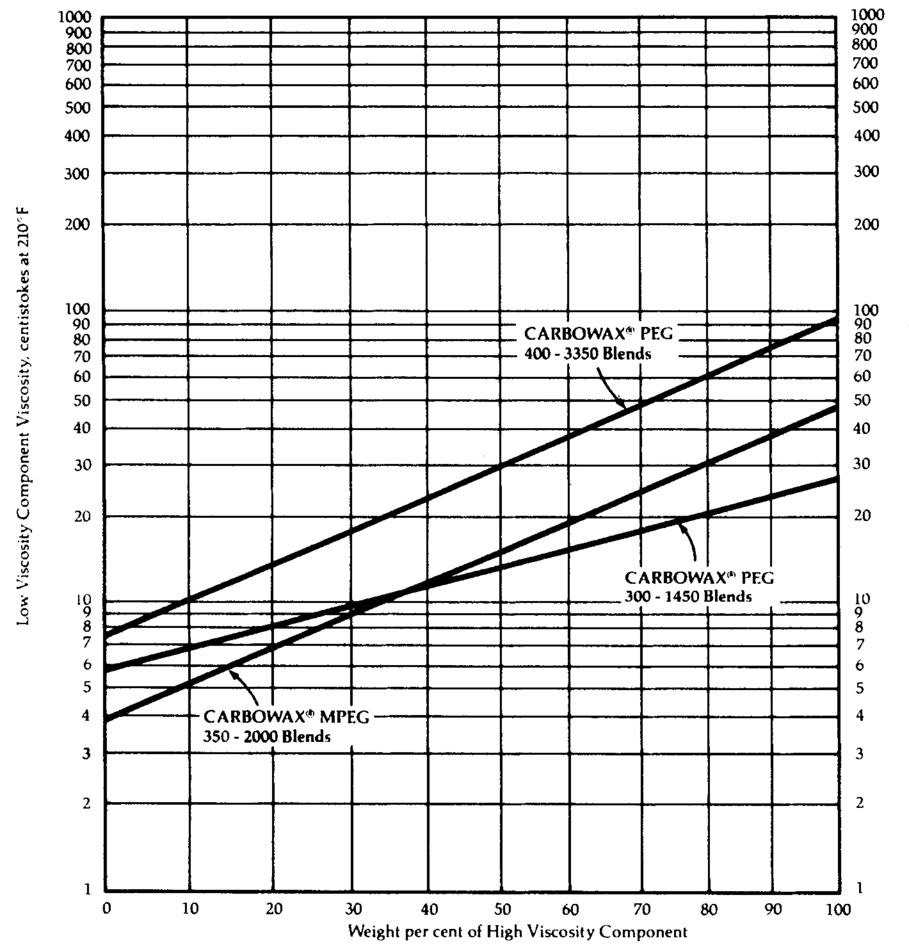
Table 11.70: (continued)

Polymer Distribution in CARBOWAX Polyethylene Glycols 200, 300, 400, 600, 1000, 1450, 4600 and 8000



Note: These curves were computer-derived and confirmed by gel permeation chromatography

Approximate Kinematic Viscosity of Blends of CARBOWAX Polyethylene Glycols and Methoxypolyethylene Glycols



Note: To determine the viscosity of a blend of two polyethylene glycols, draw a straight line from the low viscosity component on the left to the component on the right. Viscosities and percentages of the components of blends are then approximated by points along this line. Deviations are greater when blending lower viscosity products with those of higher viscosity. The three curves on this page are examples.

(continued)

Table 11.70: (continued)

Solubilities of Commonly Used Substances in CARBOWAX Polyethylene Glycols 400, 540 Blend and 3350

	CARBOWAX Polyethylene Glycol 400	CARBOWAX Polyethylene Glycol 540 Blend	CARBOWAX Polyethylene Glycol 3350
Nitrocellulose	Soluble	Soluble	Partly soluble
Ethyl Cellulose	Insoluble	Insoluble	Insoluble
Methyl Cellulose	Partly soluble	Insoluble	Insoluble
Shellac	Partly soluble	Partly soluble	Insoluble
Carnauba Wax (No. 3)	Insoluble	Insoluble	Insoluble
Paraffin Wax	Insoluble	Insoluble	Insoluble
Beeswax	Insoluble	Insoluble	Insoluble
Ester Gum	Insoluble	Insoluble	Insoluble
Rosin	Soluble	Partly soluble	Partly soluble
Gum Arabic	Insoluble	Insoluble	Insoluble
Raw Castor Oil	Insoluble	Insoluble	Insoluble
Tung Oil	Insoluble	Insoluble	Insoluble
Mineral Oil	Insoluble	Insoluble	Insoluble
Olive Oil	Insoluble	Insoluble	Insoluble
Pine Oil	Soluble	Partly soluble	Insoluble
Casein	Soluble	Soluble	Partly soluble
Zein	Soluble	Soluble	Partly soluble
Chlorinated Starch	Soluble	Soluble	Soluble
Gelatin	Insoluble	Insoluble	Insoluble

Solubilities of CARBOWAX Polyethylene Glycols 400, 540 Blend and 3350 in Common Solvents

	CARBOWAX Polyethylene Glycol 400		CARBOWAX Polyethylene Glycol 540 Blend		CARBOWAX Polyethylene Glycol 3350	
	Approximate % by weight		Approximate % by weight		Approximate % by weight	
	at 20°C	at 50°C	at 20°C	at 50°C	at 20°C	at 50°C
Water	S	S	73	97	62	84
Methanol	S	S	48	96	35	S
Ethanol (200-proof)	S	S	<1	S	<1	S
Acetone	S	S	20	S	<1	99
Dichloroethyl Ether	S	S	44	S	25	85
Trichloroethylene	S	S	50	90	30	80
Methylene Chloride	S	(a)	S	(a)	70	(a)
CELLOSOLVE® Solvent	S	S	<1	S	<1	88
Butyl CELLOSOLVE	S	S	<1	S	<1	52
CARBITOL® Solvent	S	S	2	S	<1	63
Butyl CARBITOL	S	S	<1	S	<1	64
Ethyl Acetate	S	S	15	S	<1	93
Dimethyl Phthalate	S	S	30	90	13	74
Dibutyl Phthalate	S	S	<1	S	<1	55
Ethyl Ether	Insoluble	(a)	Insoluble	(a)	Insoluble	(a)
Isopropyl Ether	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble
Toluene	S	S	13	S	<1	S
Heptane	Insoluble	Insoluble	0.50	0.01	<0.01	<0.01

FOOTNOTES:
S = Greater than 100 g per 100 cc of solvent.
(a) Solvent boils at or below 50°C

Table 11.71: Dow Polyglycols *(23)*

Polyethylene Glycols E-Series		Average Molecular Weight	Average Freezing Point, °C	Average Viscosity, Centistokes 32°F	77°F	100°F	210°F	Flash Point PMCC, °F	Refractive Index at 25°C	Specific Gravity 25/25°C	Density Lbs/Gal at 25°C	Viscosity Index	Specific Heat Cal/g/°C at 25°C	CTFA[1] Nomenclature
CAS# 25322-68-3	E200	200	Super Cools	187	40	23	4.4	340	1.459	1.124	9.35	111	0.524	PEG-4
	E300	300	10	343	69	36	5.9	>400	1.463	1.125	9.36	118	0.508	PEG-6
	E400	400	+ 6		90	49	7.4	>450	1.465	1.125	9.36	124	0.498	PEG-8
	E600	600	+22		131	72	11	>450	1.466	1.126	9.37	154	0.490	PEG-12
	E900	900	34			100	16	>450	a	1.204	a	182	a	—
	E1000	1000	37				18	>450	a	1.214	a	—	a	PEG-20
	E1450	1450	44		SOLID		29	>450	a	1.214	a	—	a	PEG-6-32
	E3350	3350	54				93	>450	a	1.224	a	—	a	PEG-75
	E4500	4500	58				180	>450	a	1.224	a	—	a	PEG-100
	E8000	8000	60				800	>500	a	1.224	a		a	PEG-150
Methoxypoly-ethylene Glycols MPEG														
CAS# 9004-74-4	MPEG 350	350	0		27	16	3.8	>350	1.455	1.097	9.14	138	—	PEG-6 Methyl Ether
	MPEG 550	550	20		56	30	6.3	>400	1.461	1.102	9.17	181	—	PEG-10 Methyl Ether
	MPEG 750	750	30			53	9.9	>450	1.463	1.096b	9.04b	a	—	PEG-16 Methyl Ether

a Designates properties not applicable for solids
b At 50°
[1] Cosmetic, Toiletry and Fragrance Association

Liquids Miscible in all Proportions with Liquid Polyethylene Glycols E200, E300, E400, E600

Acetaldehyde
Acetic Acid (Glacial)
Acetic Anhydride
Acetone*
Acetylene Tetrabromide
Acrylonitrile
Allyl Alcohol
Allyl Bromide
Amyl Acetate
Amyl Alcohol
tert-Amyl Alcohol
Aniline
Benzaldehyde
Benzene
Benzyl Alcohol
Bromobenzene
Bromoform
n-Butyl Acetate
n-Butyl Bromide
n-Butyl Phosphate
n-Butyl Stearate
o-Chloroaniline
Chlorobenzene
Chloroform*
o-Cresol
Cyclohexanol
Cyclohexanone
Diacetone Alcohol
Dichloroacetic Acid
o-Dichlorobenzene
Dichloroethyl Ether
Methylene Chlorobromide*
Dichloroisopropyl Ether
Diethanolamine*
Diethylene Glycol*
1,4-Dioxane*
Diphenyl Oxide*
Dipropylene Glycol*
Ethanol (95%)
Ethanolamine*
Ethyl Acetate
Ethyl Bromide
Ethyl Chloroacetate
Ethyl Lactate
Ethylene Chlorohydrin
Ethylene Dibromide*
Ethylene Dichloride*
Ethylene Glycol*
Ethylidene Dichloride
Formamide
Furfural
Glycerine*
Hydrochloric Acid (conc.)*
Isophorone
Isopropanol (99%)
Isopropyl Bromide
Lactic Acid (85%)
Mesityl Oxide
Methanol
Methyl Chloroform*
(1,1,1-trichloroethane)
4-Methylcyclohexanol
Methylene Bromide
Methylene Chloride*
Methyl Ethyl Ketone
Methyl Formate
Methyl Isobutyl Carbinol
Methyl Isobutyl Ketone
Methyl Salicylate*
Morpholine*
Nitrobenzene
Nitroethane
Nitromethane
1-Nitropropane
2-Nitropropane
Octyl Alcohol
Paraldehyde
Phenetole
Phenyl Acetate
Phenyl Ethyl Acetate
Phenyl Ethyl Alcohol
4-Phenyl-m-Dioxane
Phosphoric Acid (85%)
Piperidine
n-Propanol
Propylene Dibromide
Propylene Dichloride*
Pyridine
Styrene Oxide
Tetrahydrofurfuryl Alcohol
Triacetin
Trimethylene Bromide
Trimethylene Chlorobromide
Tripropylene Glycol*
Water

*Available from Dow
(Temp. = 75°F)

(continued)

Table 11.71: (continued)

Liquids Insoluble or Partly Soluble in the Liquid Polyethylene Glycols

	Approximate Solubility, Volume Percent			
	E200	E300	E400	E600
n-Butyl Stearate	Ins.	Ins.	Ins.	Ins.
Butyraldehyde	Ins.	Ins.	Ins.	Ins.
Carbon Disulfide	10%	10%	10%	25%
Carbon Tetrachloride*	40%	45%	Sol.	Sol.
Castor Oil	Ins.	Ins.	Ins.	Ins.
Cod Liver Oil	Ins.	Ins.	Ins.	Ins.
Cottonseed Oil	Ins.	Ins.	Ins.	Ins.
Cyclohexane	Ins.	Ins.	Ins.	Ins.
Decahydronaphthalene	Ins.	Ins.	Ins.	Ins.
Diamylnaphthalene	Ins.	Ins.	Ins.	Ins.
Dibutyl Sebacate	Ins.	Ins.	Ins.	Ins.
Diethylbenzene*	Ins.	Ins.	10%	25%
Diethyl Ether	25%	25%	25%	25%
Diisopropylbenzene	Ins.	Ins.	Ins.	Ins.
Dodecyl Alcohol	Ins.	Ins.	Ins.	Ins.
Ethylbenzene*	10%	35%	75%	Sol.
Ethylcylohexane	Ins.	Ins.	Ins.	Ins.
Gasoline	Ins.	Ins.	Ins.	Ins.
Isopropylbenzene	Ins.	25%	35%	Sol.
Isopropyl Chloride	25%	55%	Sol.	Sol.
Kerosene	Ins.	Ins.	Ins.	Ins.
Lard Oil	Ins.	Ins.	Ins.	Sol.
Lemon Oil	Ins.	Ins.	Ins.	Ins.
Methyl Laurate	Ins.	Ins.	Ins.	Ins.
alpha-Methylstyrene	35%	Sol.	Sol.	Sol.
Olive Oil	Ins.	2%	10%	30%
Orange Oil	Ins.	Ins.	Ins.	Ins.
Pentachlorodiphenyl Oxide	Ins.	Sol.	Sol.	Sol.
Perchloroethylene*	Ins.	Ins.	10%	25%
Ricinoleic Acid	Ins.	Ins.	Ins.	Ins.
Soya Oil	Ins.	Ins.	Ins.	Ins.
Sperm Oil	Ins.	Ins.	Ins.	1%
Tetrahydronaphthalene	10%	25%	45%	Sol.
Tributyl Aconitate	Ins.	Ins.	Ins.	10%
Triethylbenzene	Ins.	Ins.	Ins.	Ins.
Xylene	10%	35%	65%	Sol.

Sol. - Soluble in all proportions
Ins. - Insoluble
(Temp. = 75 °F)

*Available from Dow

Solubility of Polyethylene Glycols in Various Solvents

	E200	E300	E400	E600	E1000	E1450	E3350	E4500	E8000
Acetone	∞	∞	∞	∞	>100	60	<0.1	<0.1	<0.1
Benzene	∞	∞	∞	∞	>100	64	32	38	12
Ether	11.0	7.0	5	4	4	<0.1	<0.1	<0.1	<0.1
n-Heptane	<1	<1	<1	<1	1	<0.1	<0.1	<0.1	<0.1
Methanol	∞	∞	∞	∞	>100	>100	28	38	10
Water	∞	∞	∞	∞	>100	>100	>100	>100	>100

(approximate, grams per 100 grams solvent at 25 °C)

Effect of Polyethylene Glycols on Styrene-Butadiene Rubber*

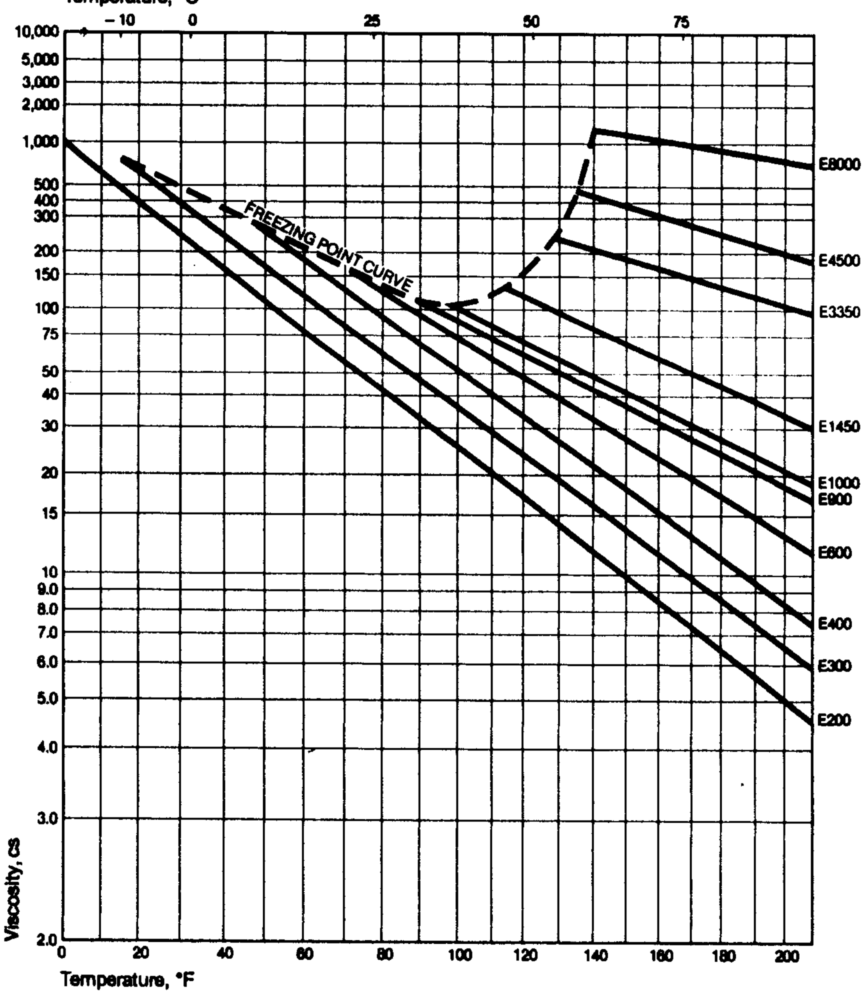
Polyglycol	% Average Dimension Change
E200	–0.18
E300	–0.18
E400	-0.18
E600	–0.27
E1000	–0.73
E1450	–0.55
E3350	-0.55
E4500	–0.73
E8000	–0.55

* Materials Styrene-Butadiene Rubber (SBR) Brake Cups – Wheel Cylinder, Part Number RM3, used for rubber swell tests. Tests carried out according to SAE procedures defined by SAE hydraulic brake fluid specification J1703a. (120 hours at 158 °F)

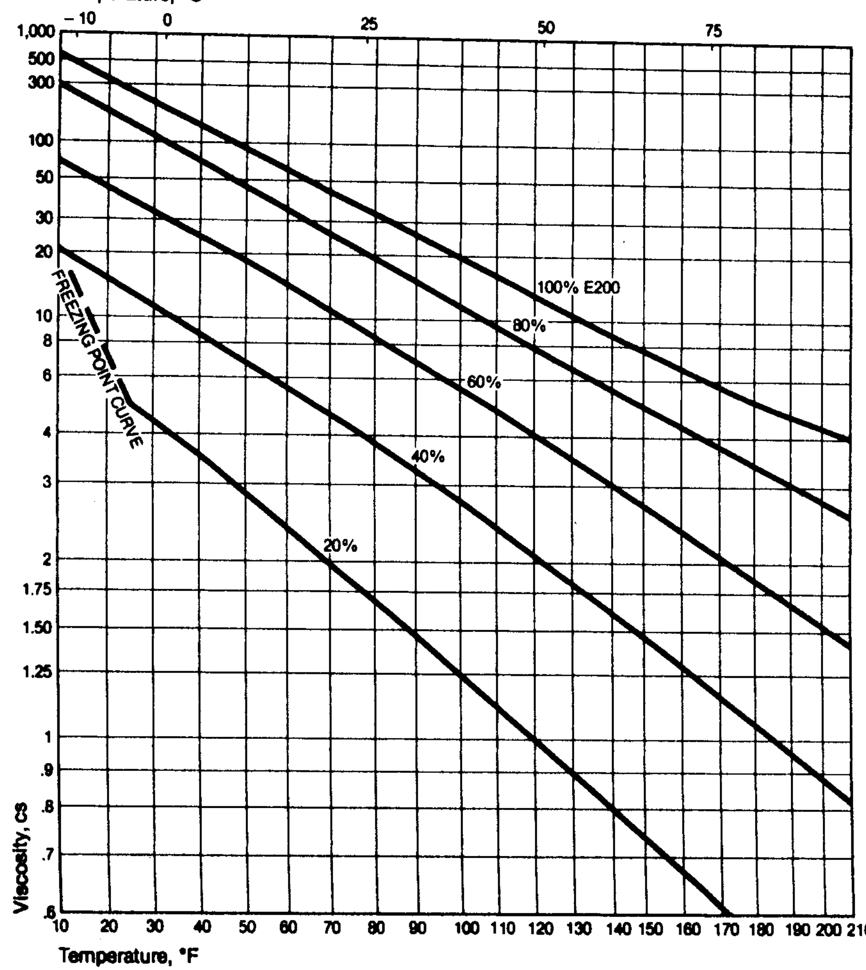
(continued)

Table 11.71: (continued)

Viscosity vs. Temperature For Dow Polyethylene Glycols



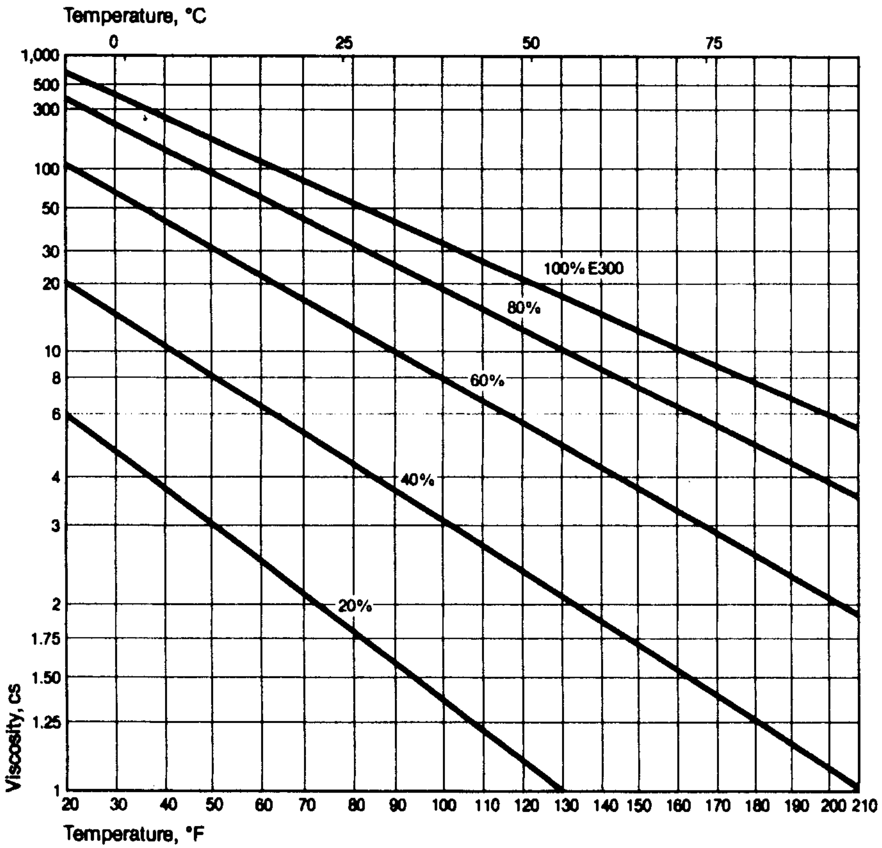
Viscosity of Aqueous Polyglycol E200 Solutions



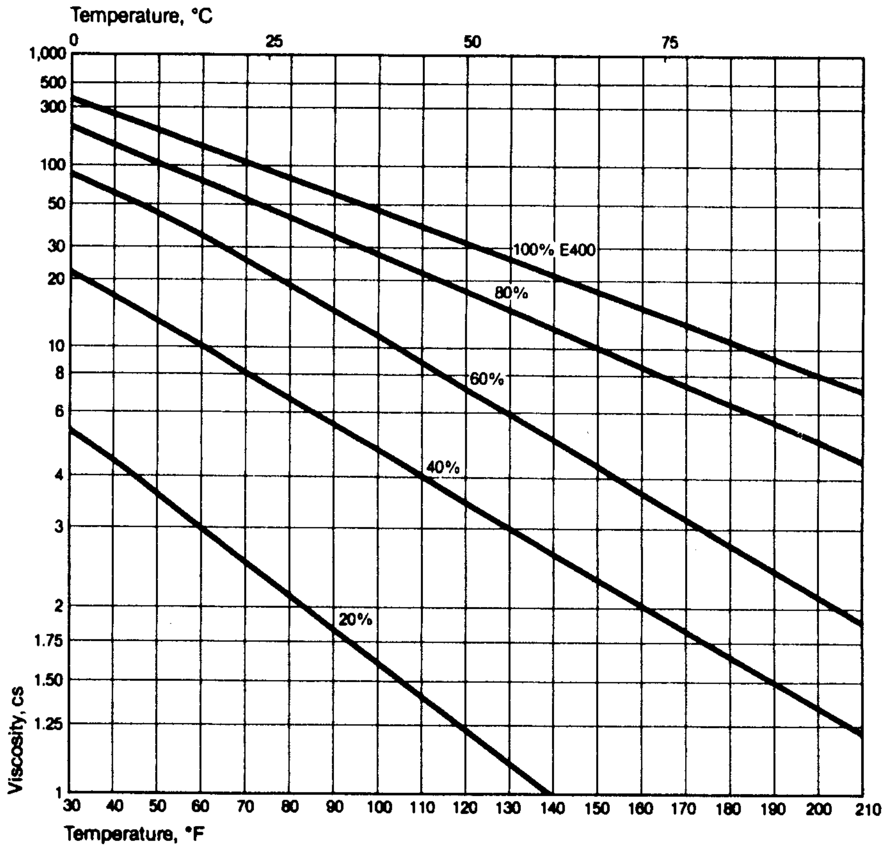
(continued)

Table 11.71: (continued)

Viscosity of Aqueous Polyglycol E300 Solutions



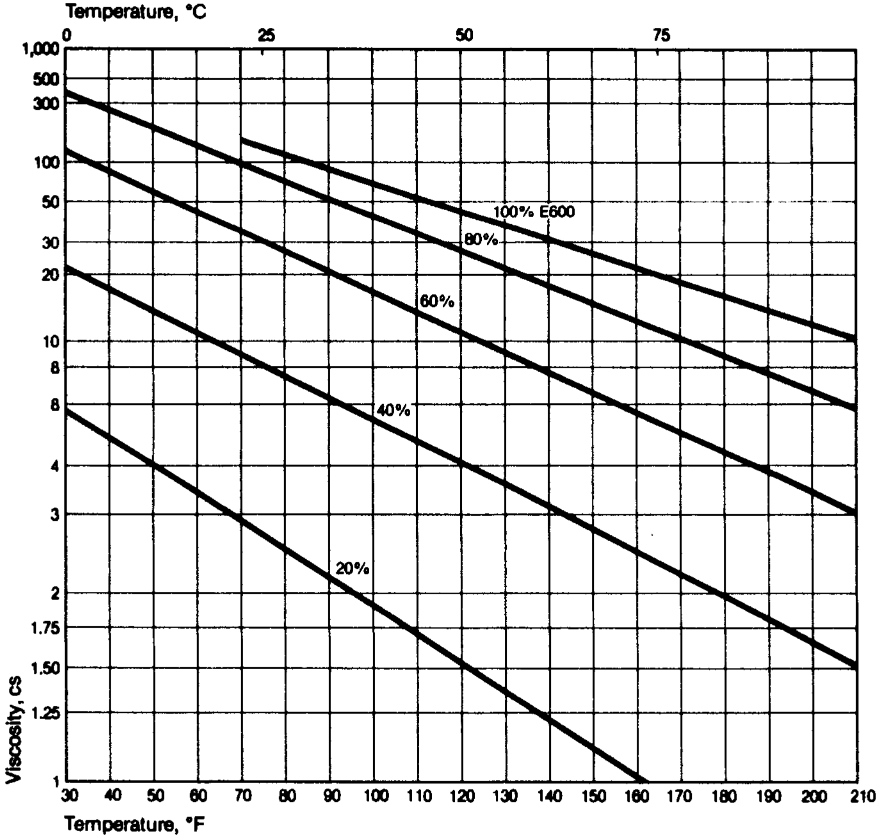
Viscosity of Aqueous Polyglycol E400 Solutions



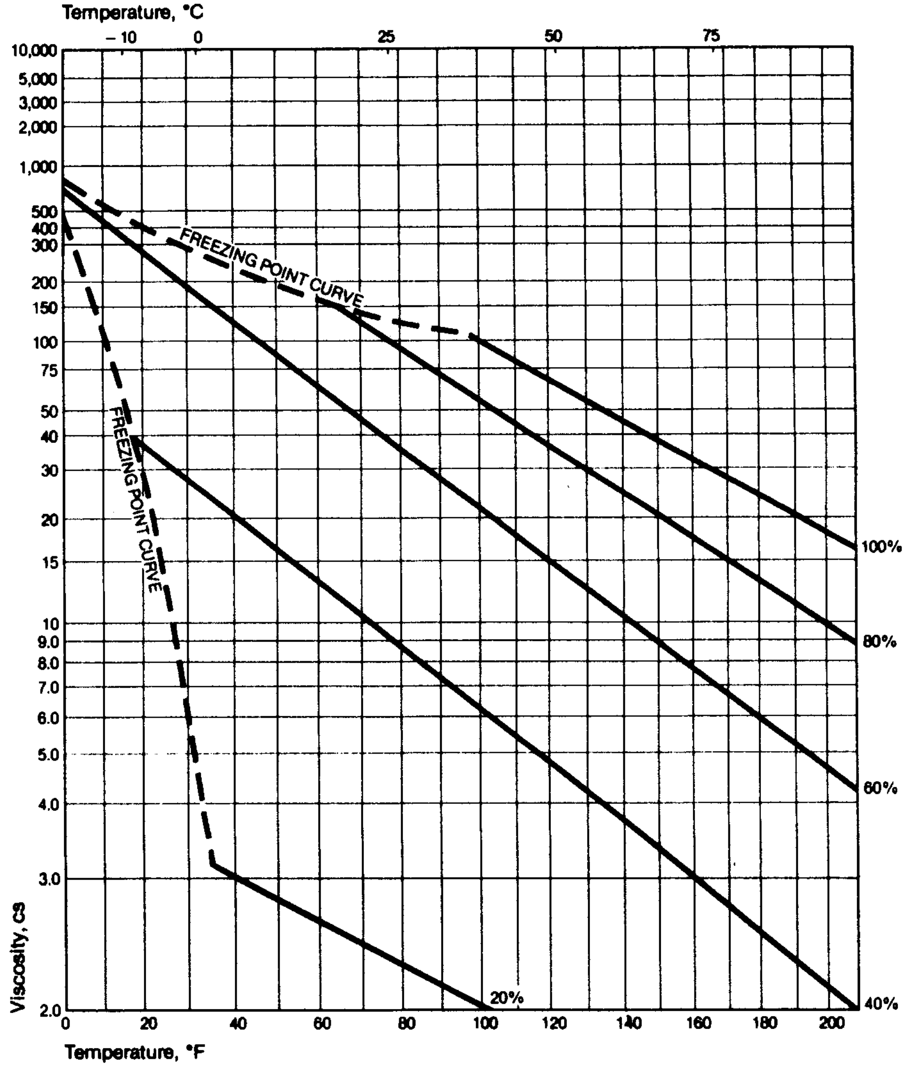
(continued)

Table 11.71: (continued)

Viscosity of Aqueous Polyglycol E600 Solutions



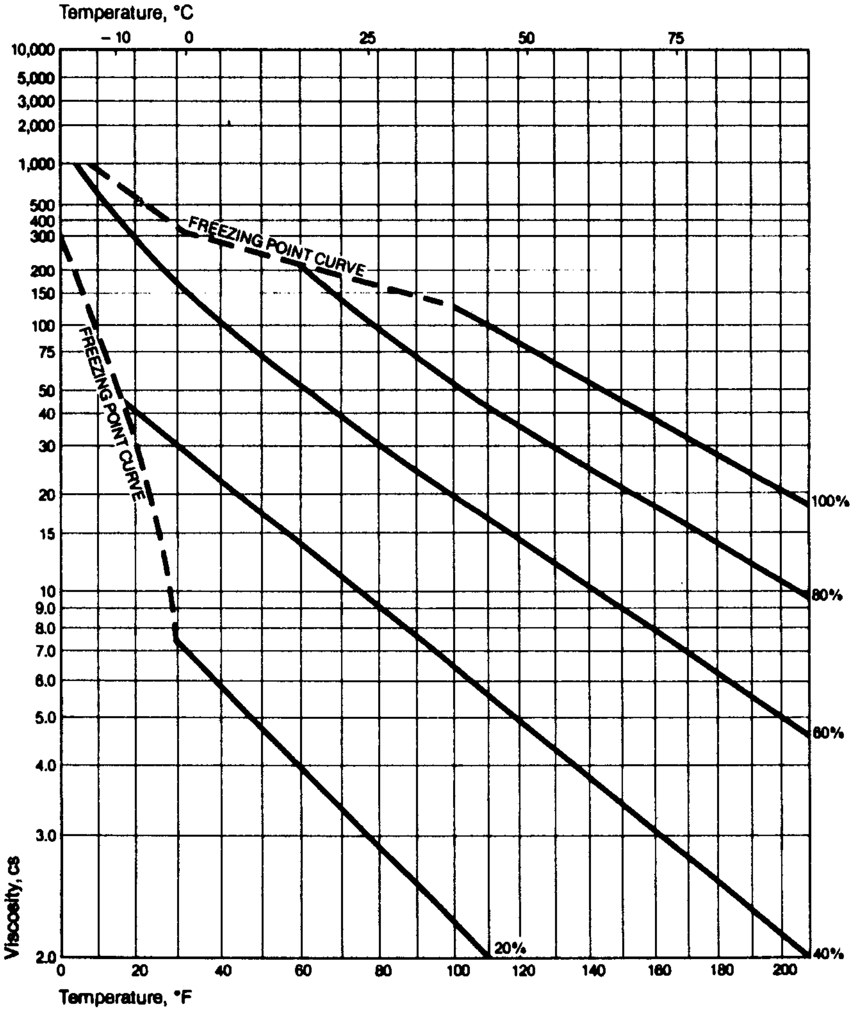
Viscosity of Aqueous Polyglycol E900 Solutions



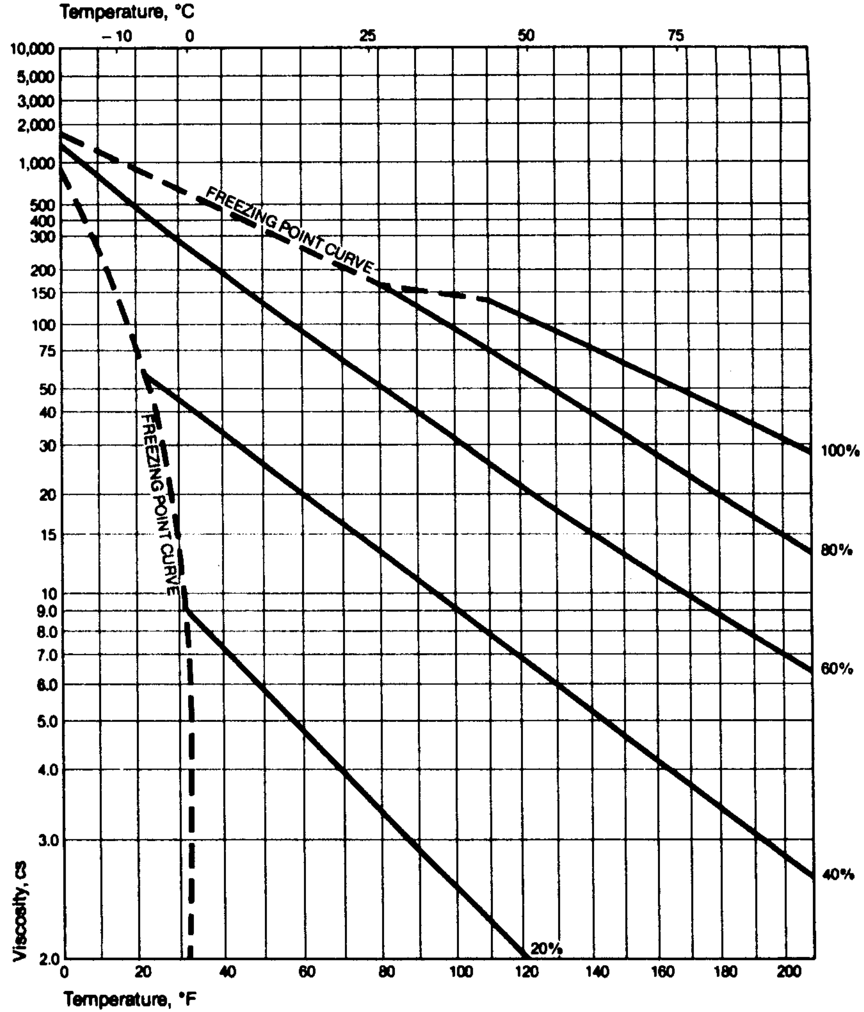
(continued)

Table 11.71: (continued)

Viscosity of Aqueous Polyglycol E1000 Solutions

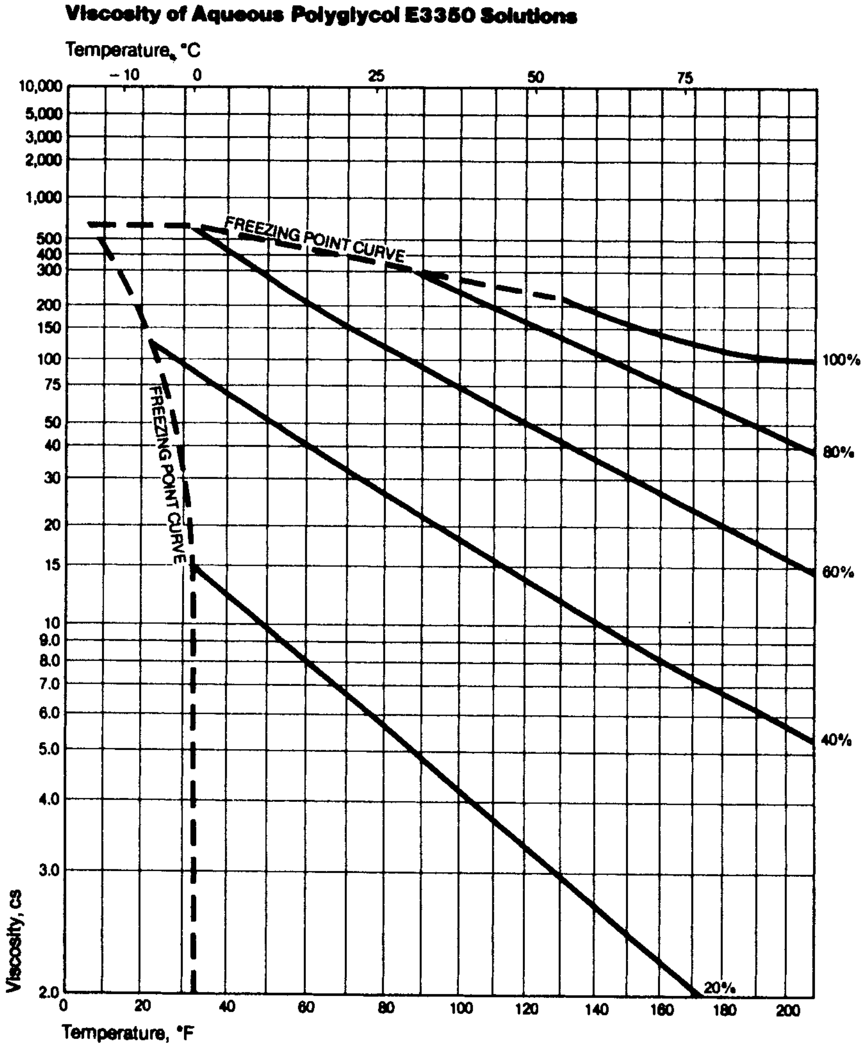


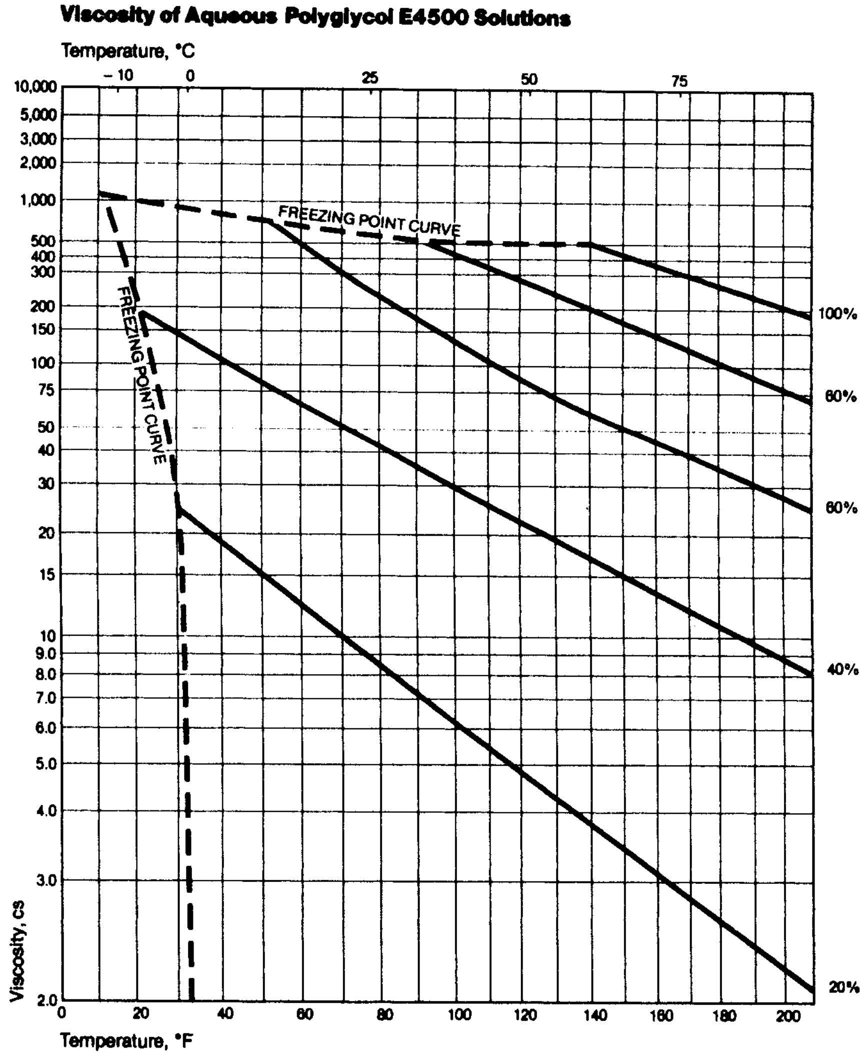
Viscosity of Aqueous Polyglycol E1450 Solutions



(continued)

Table 11.71: (continued)

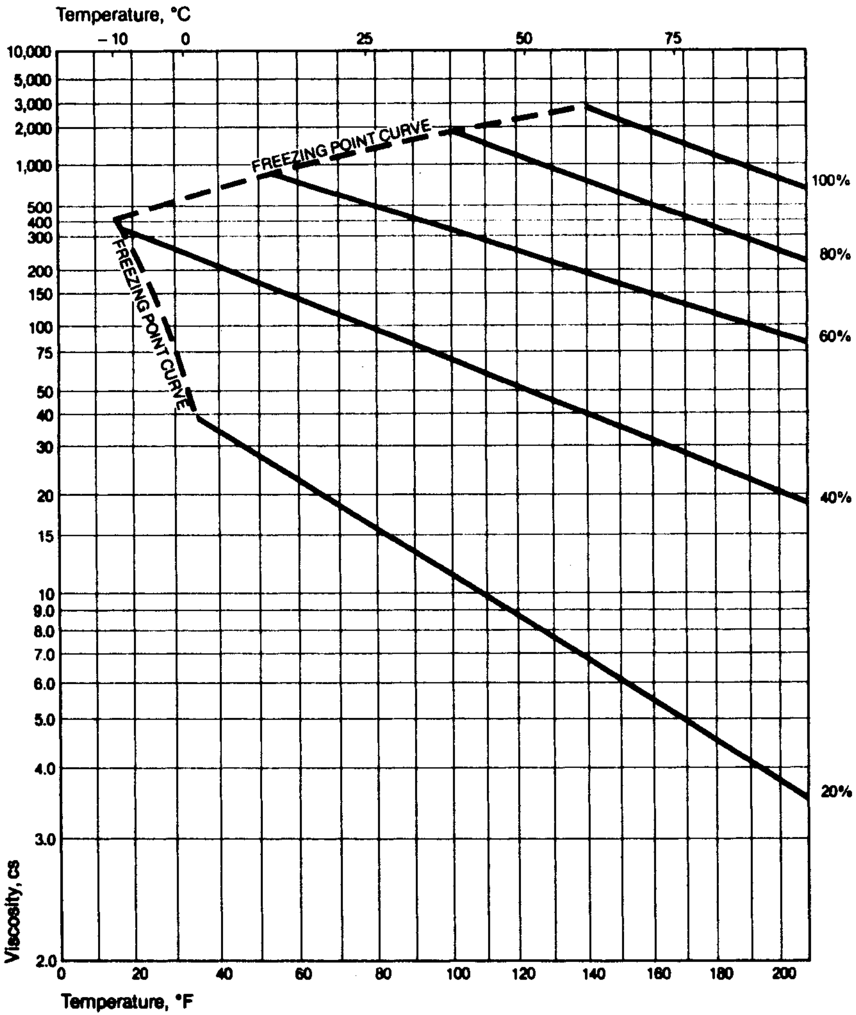




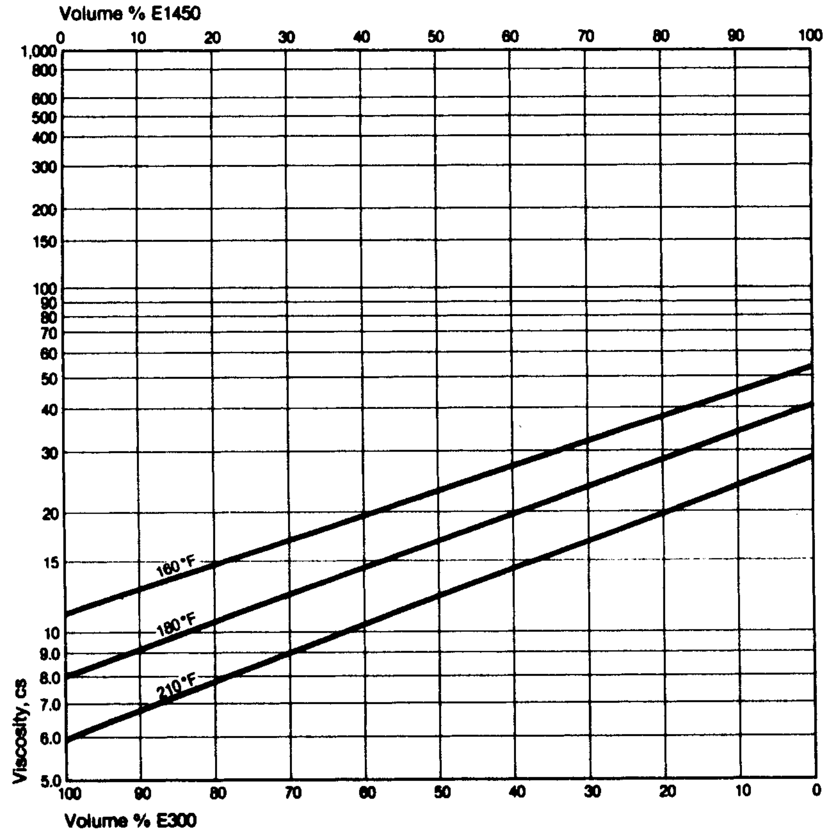
(continued)

Table 11.71: (continued)

Viscosity of Aqueous Polyglycol E8000 Solutions



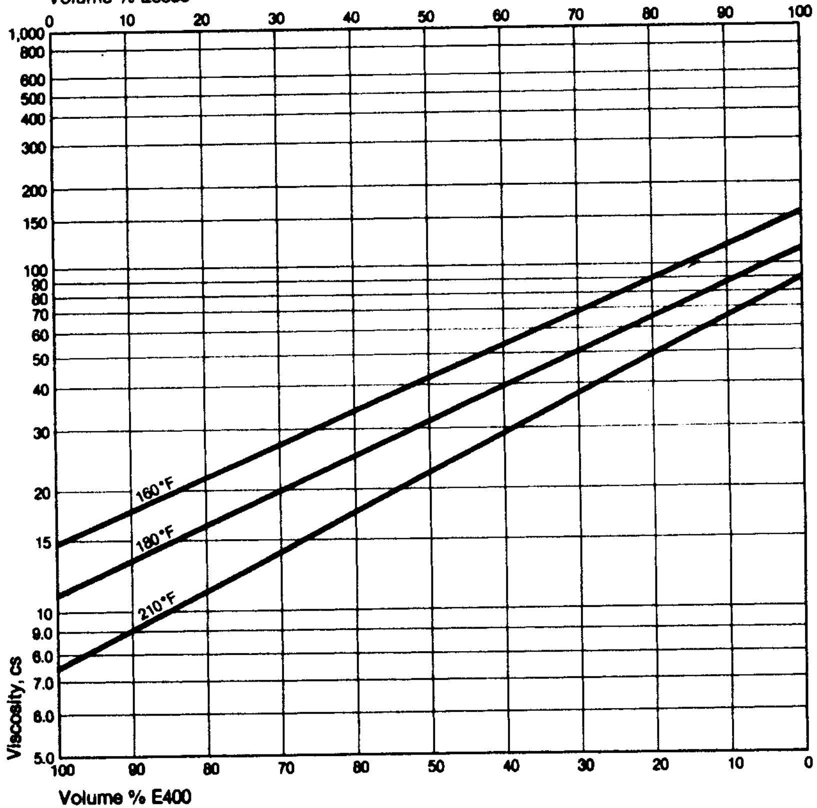
Viscosity of E300/E1450 Blends



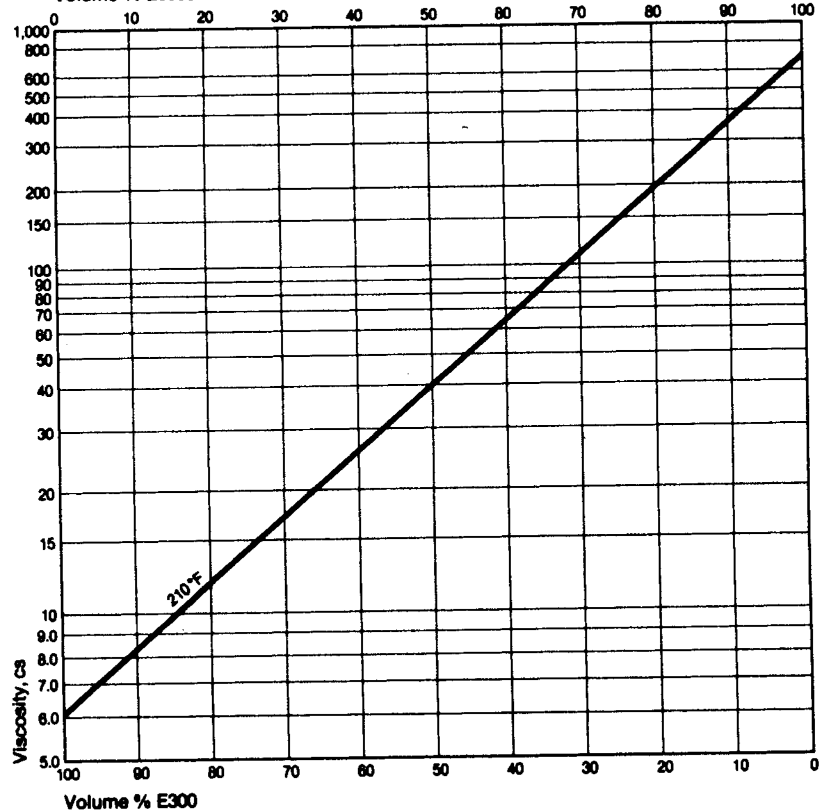
(continued)

Table 11.71: (continued)

Viscosity of E400/E3350 Blends



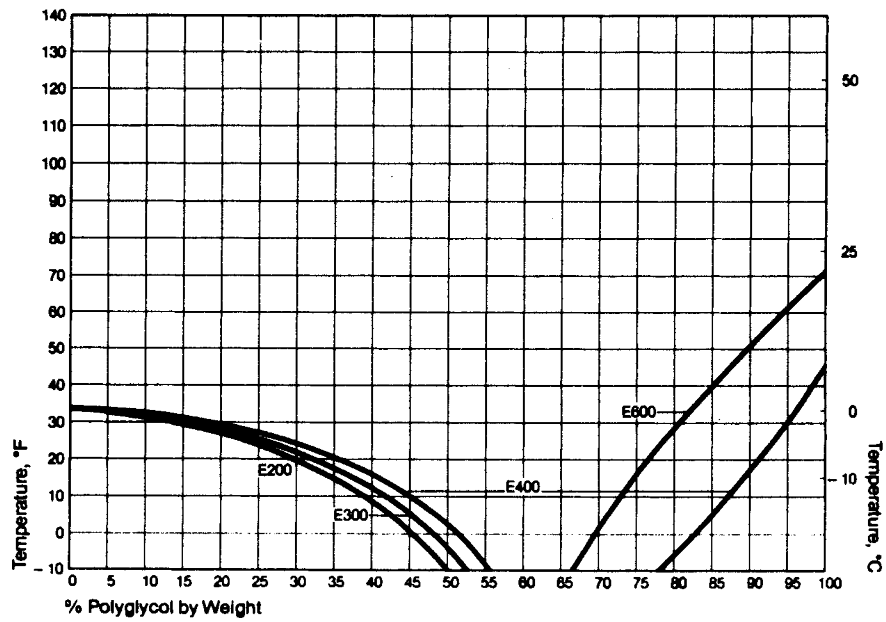
Viscosity of E300/E8000 Blends



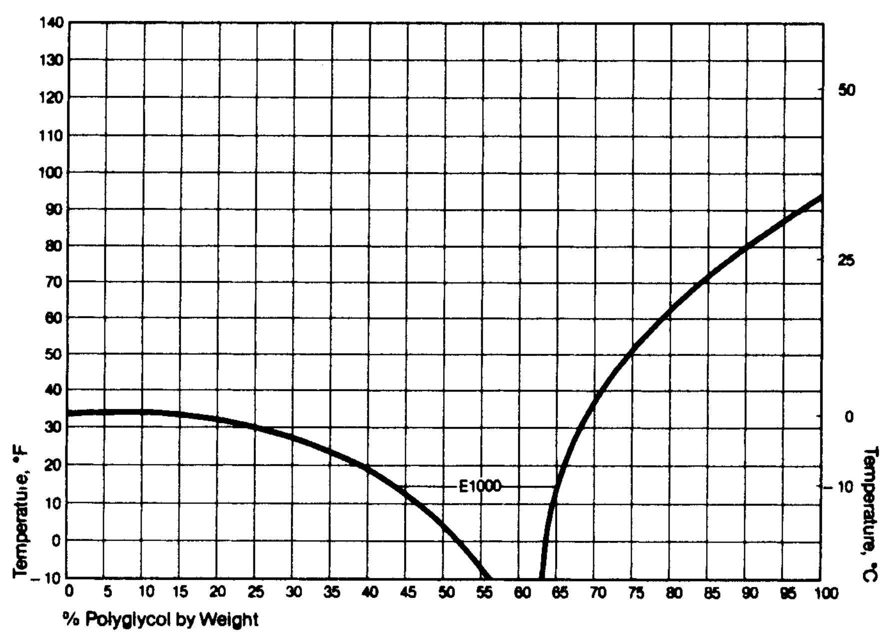
(continued)

Table 11.71: (continued)

Freezing Points — E200, E300, E400, E600 Aqueous Solutions



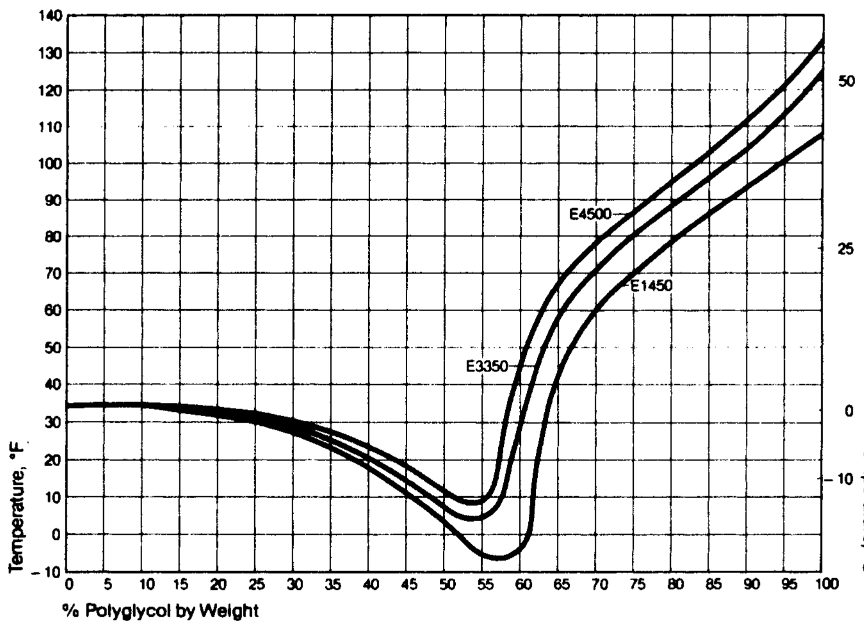
Freezing Points — E1000 Aqueous Solutions



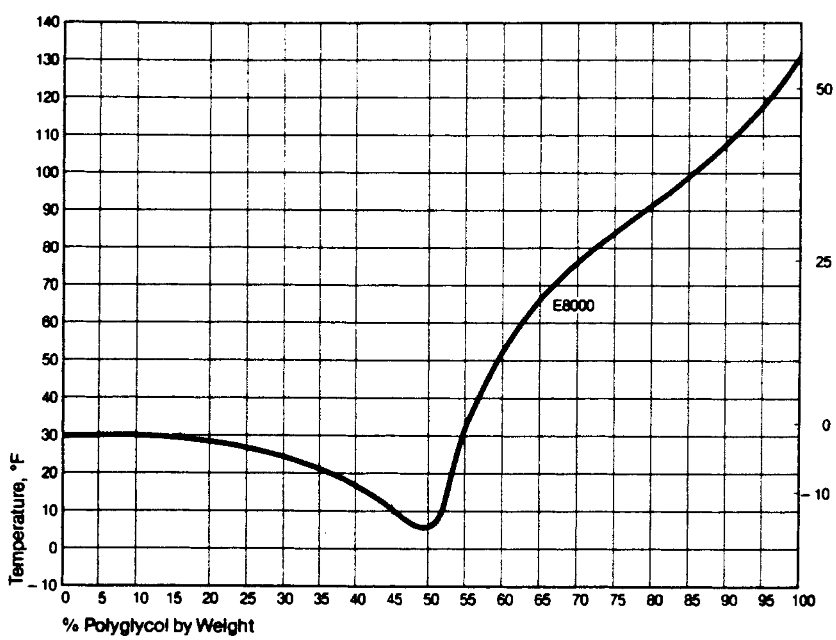
(continued)

Table 11.71: (continued)

Freezing Points — E1450, E3350, E4500 Aqueous Solutions



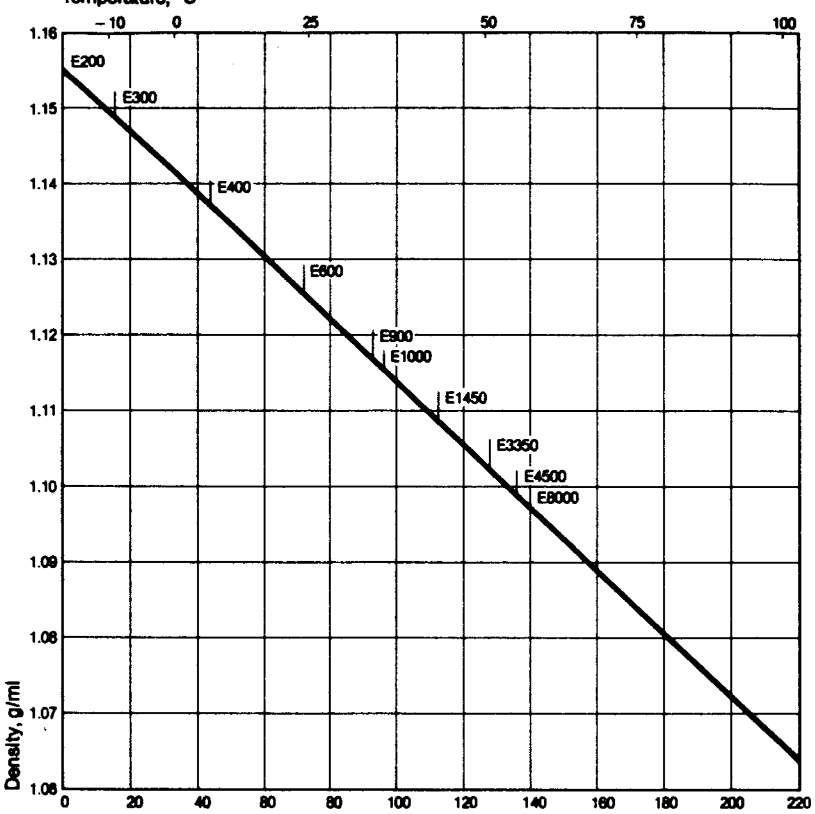
Freezing Point — E8000 Aqueous Solutions



(continued)

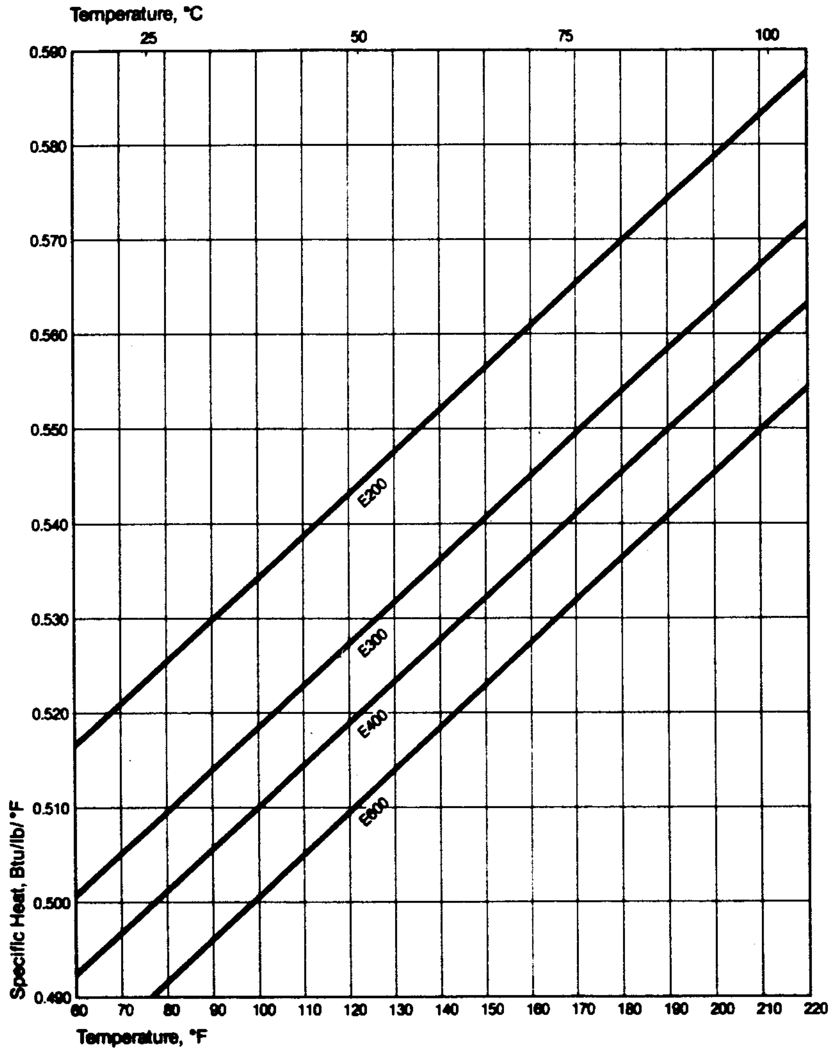
Table 11.71: (continued)

Polyethylene Glycols
Densities vs. Temperature Above Their Freezing Point



Density = 1.1548 − ($4.1624 \times 10^{-4} \times$ °F)

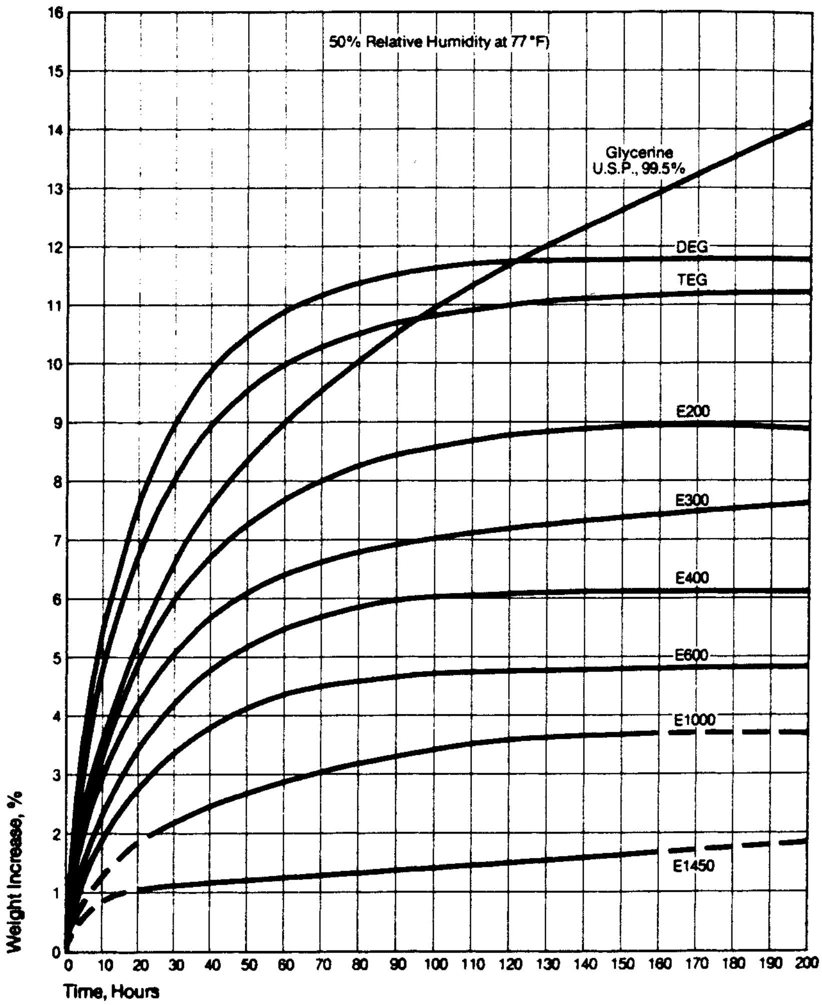
Specific Heats of Liquid Polyethylene Glycols



(continued)

Table 11.71: (continued)

Comparative Hygroscopicities



POLYPROPYLENE GLYCOLS

Table 11.72: Ashland Polypropylene Glycols *(69)*

Product	Specific Gravity 20°/20°C	Lb/Gal at 20°C	Average Molecular Weight	Pt-Co Color	Centipoise at 20°C
Polypropylene Glycol 150	1.025	8.54	150	35	82(20°C)
Polypropylene Glycol 425	1.008	8.42	425	100	80
Polypropylene Glycol 1025	1.005	8.39	1000	25	150
Polypropylene Glycol 2025	1.005	8.39	2000	75	300
Polypropylene Glycol 4000	1.004	8.36	4000	75	900

*Pensky-Martens
(a) Density @ 80°C

Table 11.73: Dow Polypropylene Glycols and Polyglycol Copolymers *(23)*

Polypropylene Glycols P-Series		Average Molecular Weight	Average Freezing Point, °C	Average Viscosity, Centistokes 32°F	77°F	100°F	210°F	Flash Point PMCC, °F	Refractive Index at 25°C	Specific Gravity 25/25°C	Density Lbs/Gal at 25°C	Viscosity Index	Specific Heat Cal/g/°C at 25°C	CTFA[1] Nomenclature
CAS# 29434-03-5	P425	425	- 45*	500	70	33	4.6	330	1.447	1.007	8.39	—	0.477	PPG-9
	P1200	1200	- 40*	1130	175	91	13.5	345	1.448	1.007	8.38	161	0.459	PPG-20
	P2000	2000	- 30*	1400	300	160	23	390	1.449	1.002	8.34	183	0.452	PPG-26
	P4000	4000	- 26*	4000	800	455	53	365	1.450	1.005	8.36	191	—	PPG-30
Polypropylene Glycols L-Series														
CAS# 9003-13-8	L910	910	- 43*	356	83	43	8	345	1.444	0.9833	8.23	181	—	PPG-14 Butyl Ether
	L1150	1150	- 40*	590	115	57	11	>400	1.446	0.9888	8.28	177	—	PPG-18 Butyl Ether
Polyglycol Copolymers														
CAS# 51258-15-2	15-200	2600	- 40*	2060	420	206	32	>450	1.460	1.060	8.81	200	0.470	PPG-24 Glycereth-24
CAS# 9082-00-2	112-2	4900	- 18*	20000	1000	445	60	455	1.455	1.028	8.56	200	0.430	PPG-66 Glycereth-12
CAS# 53637-25-5	EP530	2000	- 32*	1450	321	168	25	>420	1.452	1.017	8.46	192	—	Poloxamer-181

a Designates properties not applicable for solids
b At 50°
* Pour Point
[1] Cosmetic, Toiletry and Fragrance Association

Solubility of Additional Liquids in Polypropylene Glycols

	Approximate Solubility, Volume % P425	P1200	P2000	P4000
Diethanolamine*	Sol.	< 1	< 1	< 1
Diethylene Glycol*	Sol.	10%	10%	10%
Ethylene Glycol*	Sol.	8%	< 1	< 1
Glycerine*	< 1	< 1	< 1	< 1
Oleic Acid	< 1	Sol.	Sol.	Sol.
Polyglycol E200*	Sol.	Sol.	9%	< 1
Polyglycol E400*	Sol.	Sol.	< 1	3%
Polyglycol E600*	Sol.	Sol.	< 1	< 1
Propylene Glycol*	Sol.	Sol.	10%	5%
Sperm Oil	20%	Sol.	Sol.	Sol.
Triethanolamine*	Sol.	< 1	< 1	< 1
Triethylene Glycol*	Sol.	Sol.	9%	9%

Sol. = Soluble in all proportions
*Product of The Dow Chemical Company
(Temp. = 77°F)

(continued)

Table 11.73: (continued)

Liquids Soluble in All Proportions with Polyglycols P425, P1200, P2000 and P4000

Acetaldehyde
Acetic Acid (glacial)
Acetic Anhydride
Acetone*
Acetylene Tetrabromide
Allyl Alcohol
Allyl Bromide
Amyl Acetate
Amyl Alcohol
tert-Amyl Alcohol
Aniline
Benzaldehyde
Benzene
Benzyl Alcohol
Bromobenzene
Bromocyclohexane
Bromoform
n-Butyl Acetate
n-Butyl Bromide
n-Butyl Lactate
n-Butyl Phosphate
n-Butyraldehyde
Butyl Stearate
Caproic Acid
Carbon Bisulfide
Carbon Tetrachloride*
Castor Oil
o-Chloroaniline
Chloroform*
o-Chlorophenol
Cod Liver Oil
Cottonseed Oil
Cresol†
Cyclohexane
Cyclohexanol
Cyclohexanone
Decahydroaphthalene
Diacetone Alcohol
Diamylnaphthalene
Di-n-butylamine
Dibutyl Sebacate
Dichloroacetic Acid
o-Dichlorobenzene
Dichlorodiphenyl Oxide
Dichloroethyl Ether
Dichloroisopropyl Ether
Diethylbenzene*
Diethyl Ether
Diisopropylbenzene
1,4-Dioxane*
Diphenyl Oxide*
Dipropylene Glycol*
Dodecyl Alcohol
Ethanol (95%)
Ether
Ethyl Acetate
Ethylbenzene*
Ethyl Bromide
Ethyl Chloroacetate
Ethyl Cyanoacetate
Ethylcyclohexane
Ethyl Lactate
Ethylene Chlorohydrin
Ethylene Dibromide*
Ethylene Dichloride*
Ethylidene Dichloride
Furfural
n-Heptane
Hydrochloric Acid (23°Be.)*
Isophorone
Isopropyl Alcohol (99%)
Isopropylbenzene
Isopropyl Bromide
Isopropyl Chloride
Lactic Acid (85%)
Lard Oil
Lemon Oil
Mesityl Oxide
Methanol
Methyl Chloroform*
4-Methylcyclohexanol
Methylene Bromide
Methylene Chloride*
Methylene Chlorobromide
Methyl Ethyl Ketone
Methyl Formate
Methyl Isobutyl Carbinol
Methyl Isobutyl Ketone
Methyl Laurate
Methyl Salicylate*
a-Methylstyrene
Morpholine*
Nitrobenzene
Nitroethane
Nitromethane
1-Nitropropane
2-Nitropropane
Octyl Alcohol
Olive Oil
Orange Oil
Paraldehyde
Pentachlorodiphenyl Oxide
Perchloroethylene*
Phenyl Ethyl Acetate
Phenyl Ethyl Alcohol
Phenetole
Phenyl Acetate
4-Phenyl-m-dioxane
Pine Needle Oil
Piperidine
Propyl Alcohol
Propylene Dibromide
Propylene Dichloride*
Pyridine
Ricinoleic Acid
Soya Oil
Styrene Oxide
Tetrachloroethane
Tetrahydrofurfuryl Alcohol
Tetrahydronaphthalene
Triacetin
Tributyl Aconitate
1,1,2-Trichloroethane*
Trichloroethylene*
Triethylbenzene
Trimethylene Bromide
Trimethylene Chlorobromide
Tripropylene Glycol*
Vinyl Cyanide
Xylene

*Product of The Dow Chemical Company
†Heat evolved on mixing
(Temp. = 77°F)

Solubility of Aliphatic Hydrocarbons in Polypropylene Glycols

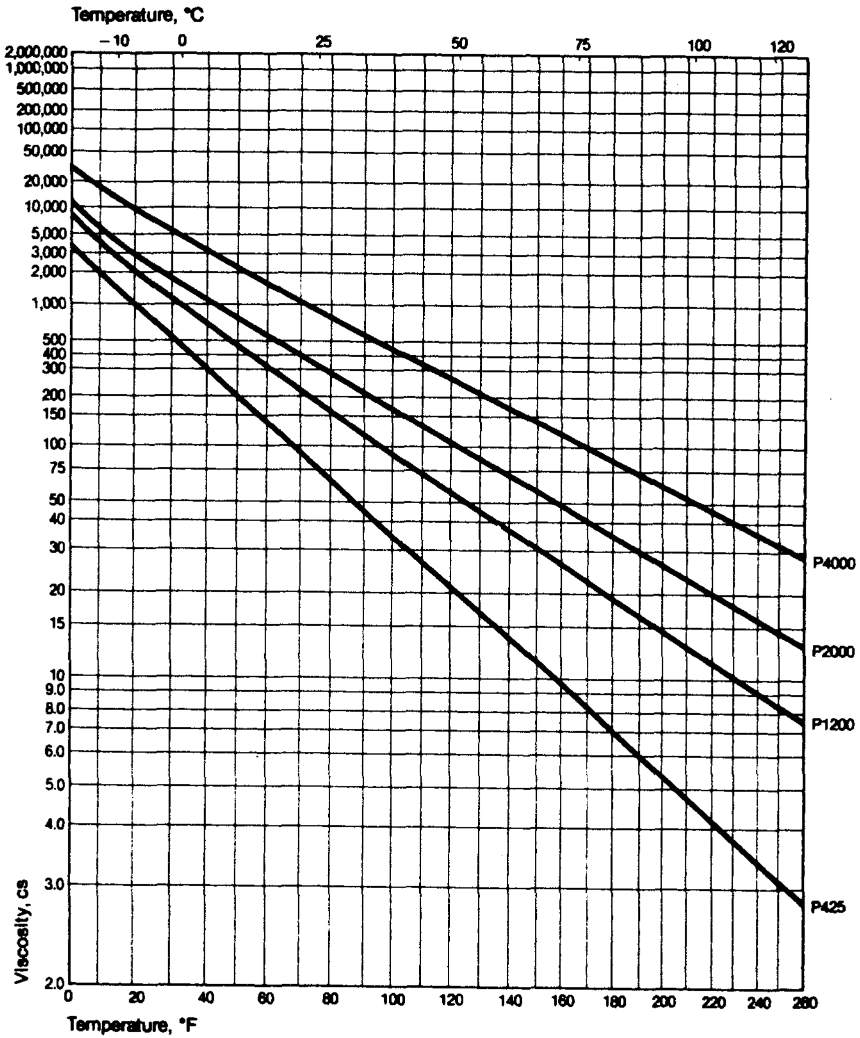
	Approximate Solubility, Volume %							
	P425		P1200		P2000		P4000	
	77°F	120°F	77°F	120°F	77°F	120°F	77°F	120°F
Hexane	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.
VM and P Naphtha	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.
No. 2 Fuel Oil	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.
Mineral Spirits	35%	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	
Hi Flash Naphtha	30%	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.
SAE 20 Lube Oil	15%	20%	25%	Sol.	30%	Sol.	16%	28%
Light Paraffin Oil	5%	10%	20%	40%	25%	Sol.	18%	22%
Heavy Mineral Oil	2%	10%	5%	15%	10%	20%	8%	13%

The solubility of aliphatic hydrocarbons in polyglycols P425, P1200, and P2000 diminishes with an increase in the chain length of the hydrocarbon.
Sol. = Soluble in all proportions

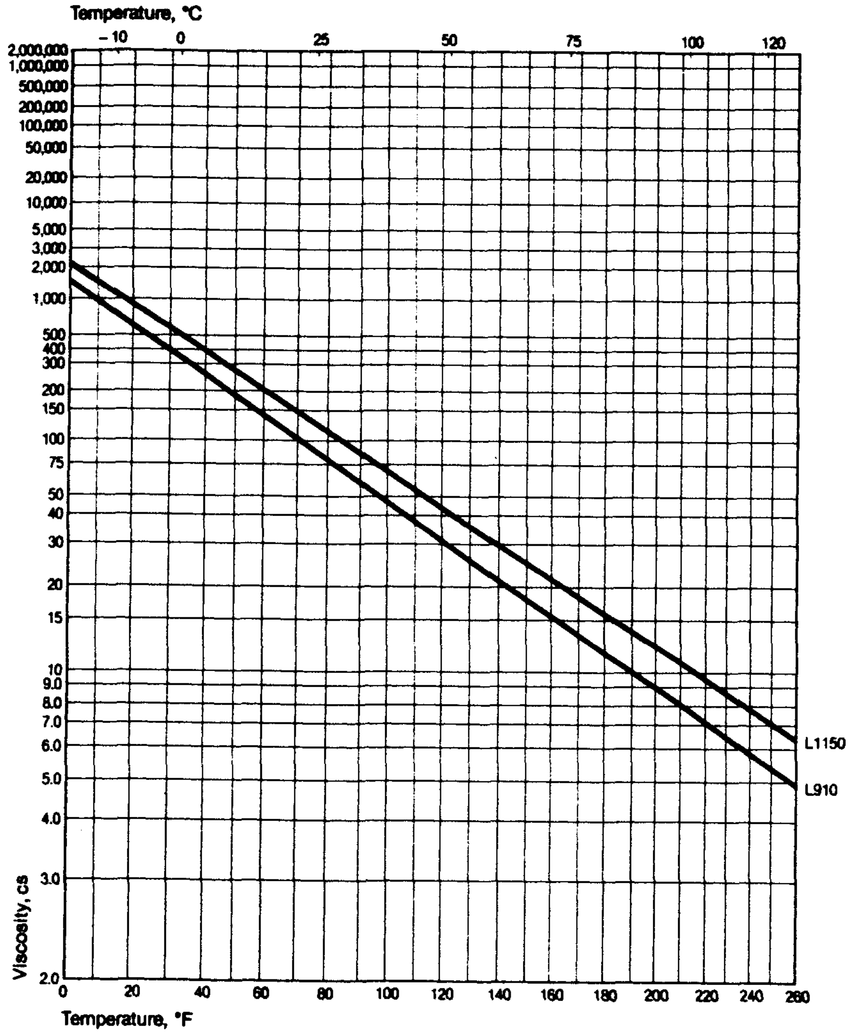
(continued)

Table 11.73: (continued)

Viscosity vs. Temperature For Polypropylene Glycols — P-Series



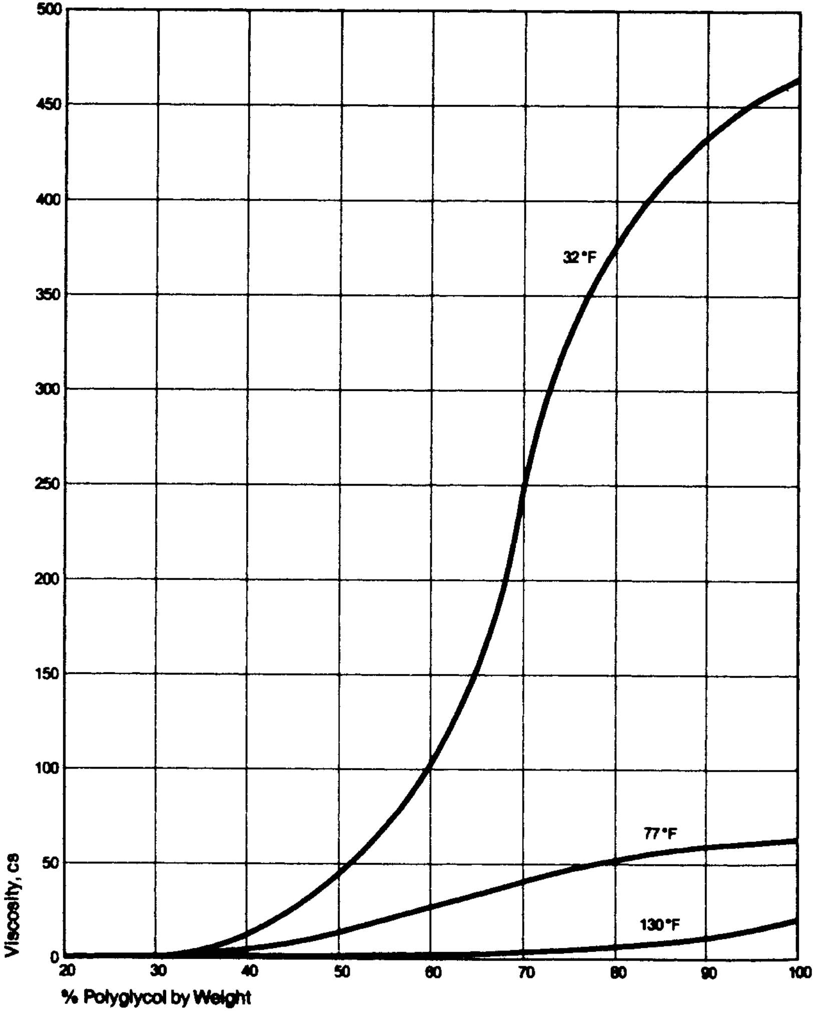
Viscosity vs. Temperature For Polypropylene Glycols — L-Series



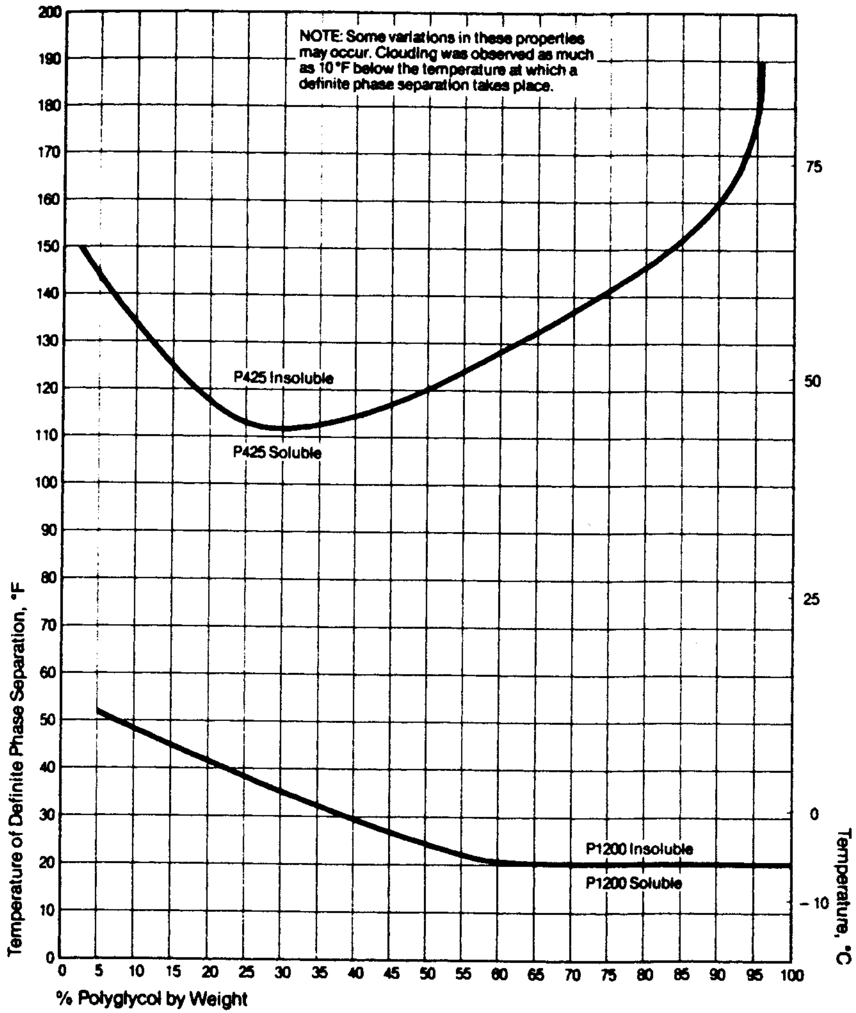
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Table 11.73: (continued)

Viscosity of Aqueous Solutions of Polyglycol P425



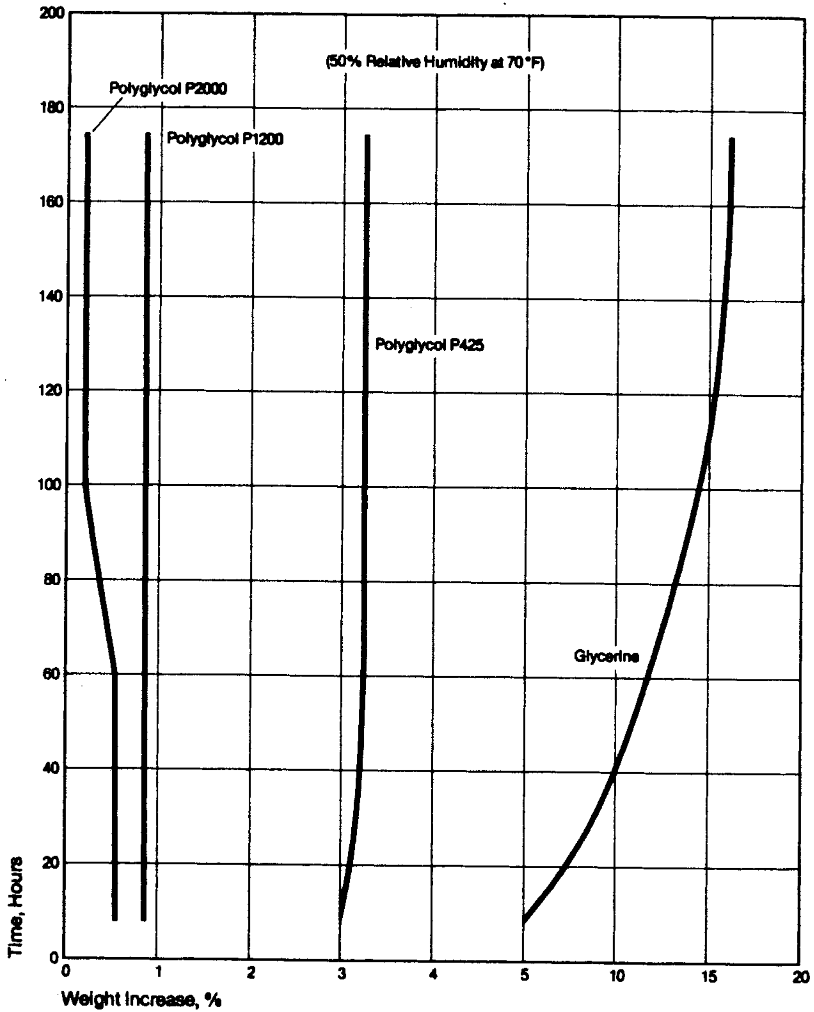
Water Solubility of Polypropylene Glycols P425 and P1200



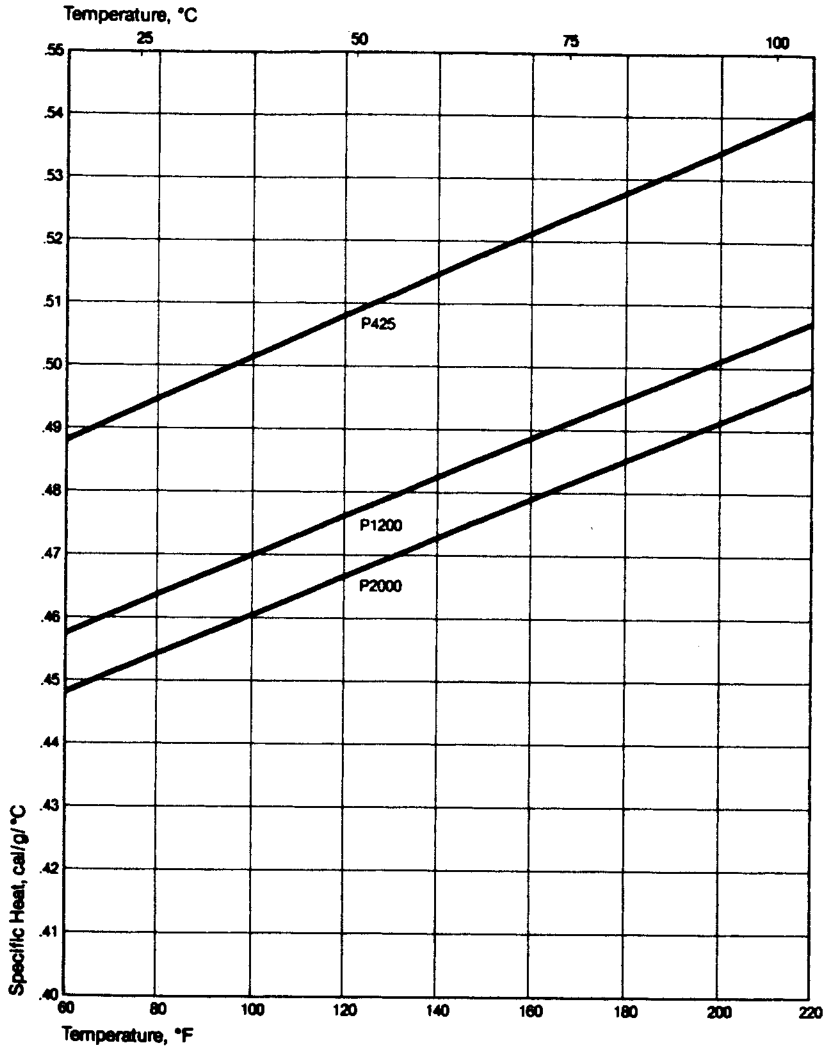
(continued)

Table 11.73: (continued)

Comparative Hygroscopicity of P-Series Polypropylene Glycols and Glycerine



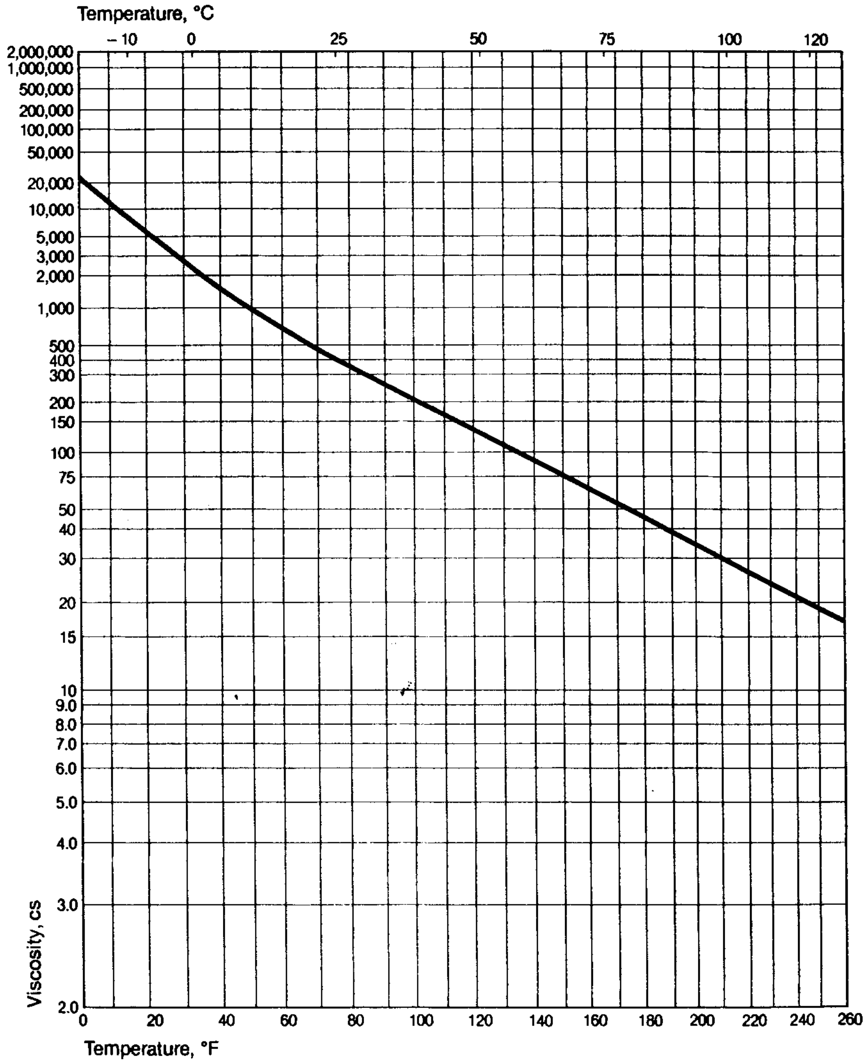
Specific Heats of Polypropylene Glycols — P-Series



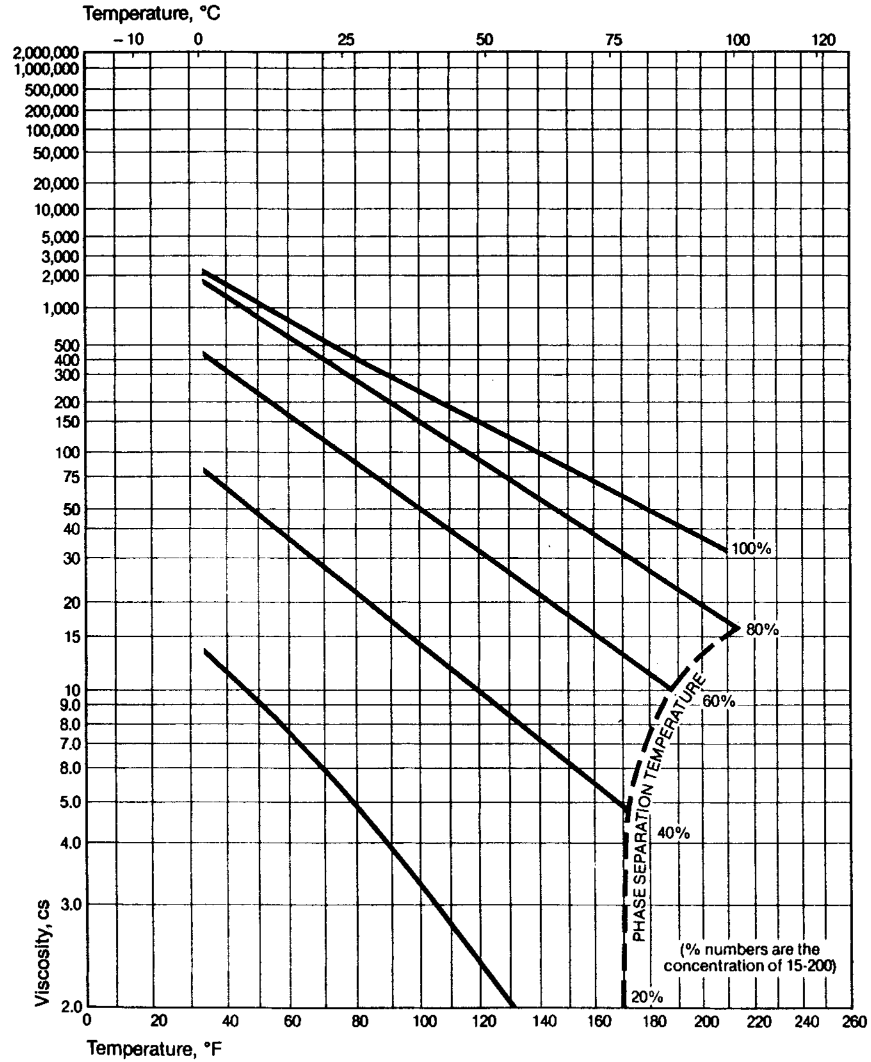
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Table 11.73: (continued)

Viscosity vs. Temperature for Polyglycol 15-200



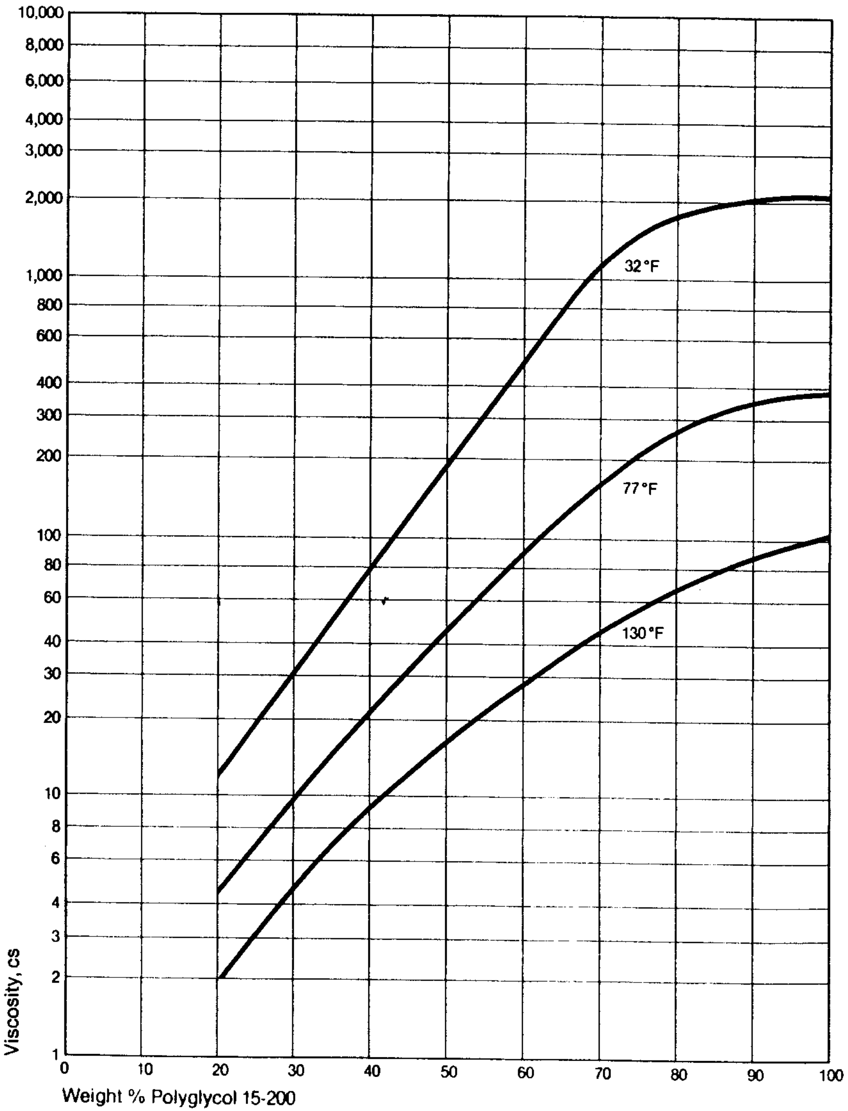
Viscosity vs. Temperature of Aqueous Polyglycol 15-200 Solutions



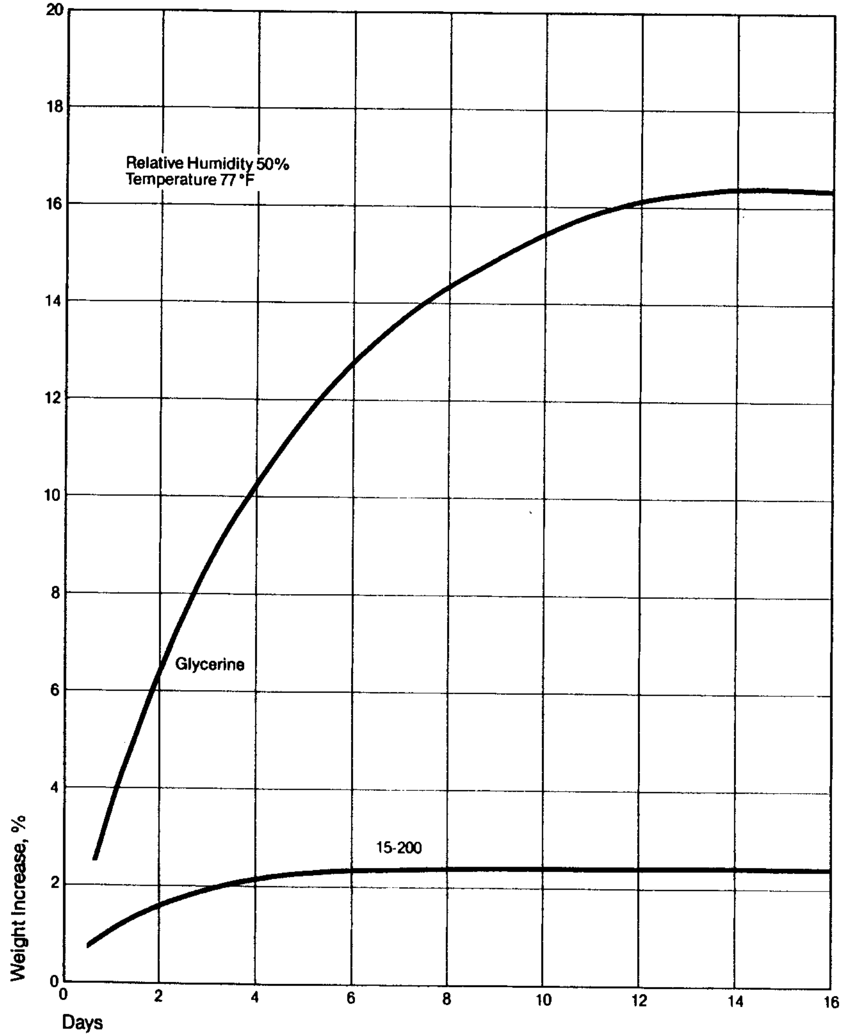
(continued)

Table 11.73: (continued)

Viscosity vs. Concentration of Aqueous Polyglycol 15-200 Solutions



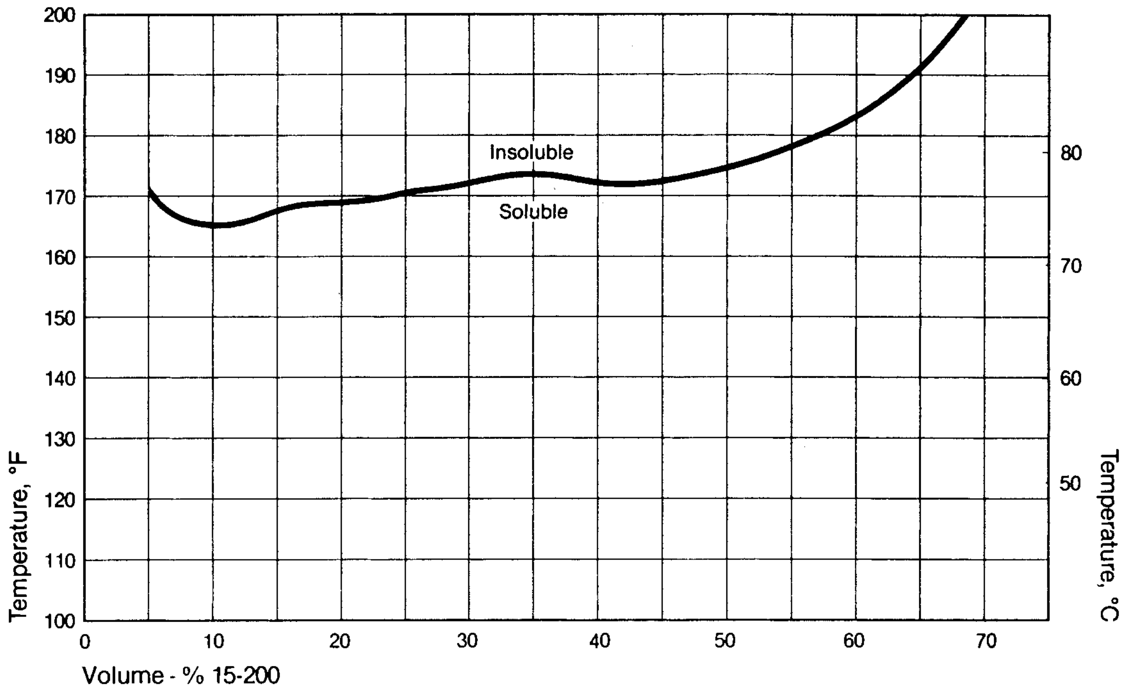
Hygroscopicity of Polyglycol 15-200



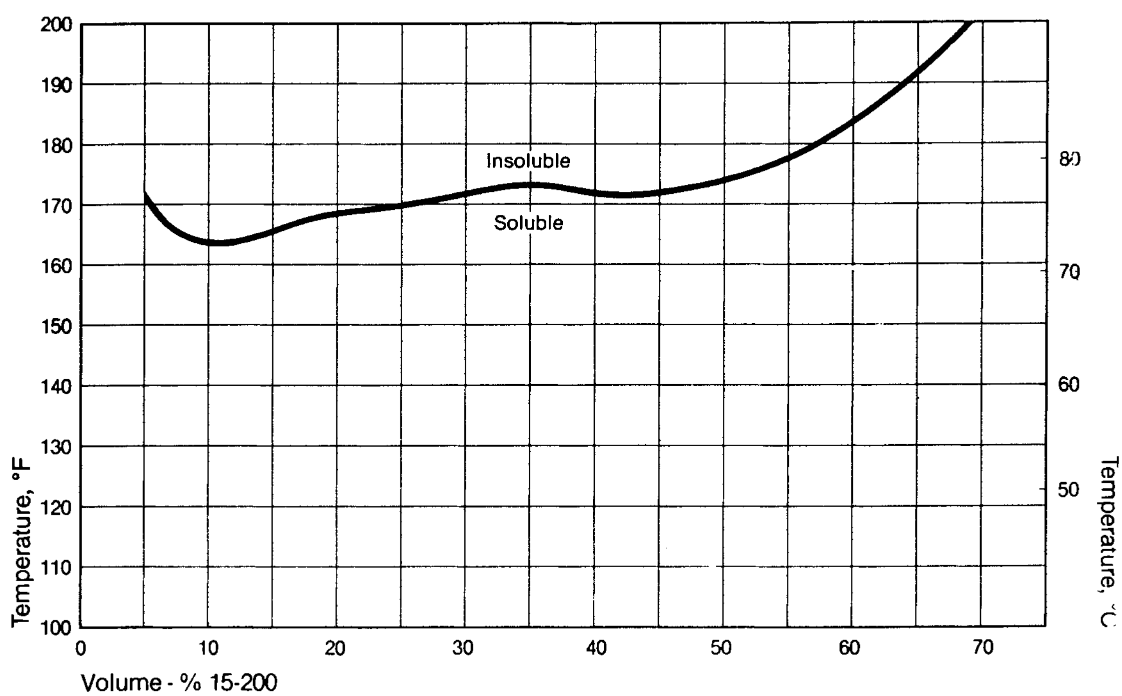
(continued)

Table 11.73: (continued)

15-200 Cloud Point in Water



Polyglycol 15-200 Separation Temperature in Water



(continued)

Table 11.73: (continued)

Solubility of Organic Liquids in Polyglycol 15-200

Organic Liquid	Solubility, %
Butyl Stearate	10
Cotton Seed Oil	>90
Cyclohexane	44
Decahydronaphthalene	36
Diethanolamine*	Ins.
Ethyl Cyclohexane	44
Ethylene Glycol*	25
Gasoline	25
Glycerine*	Ins.
Lard Oil	Ins.
Olive Oil	Ins.
Soya Oil	Ins.
Triethanolamine*	Ins.

Ins. = Insoluble in all proportions.

Organic Liquids Completely Soluble in Polyglycol 15-200

At 77°F, Polyglycol 15-200 is soluble in all proportions with organic acids, alcohols, aldehydes, aromatics, halogenated hydrocarbons, glycols, glycol ethers, and some vegetable, animal and certain fruit oils. Specific compounds which are completely soluble include:

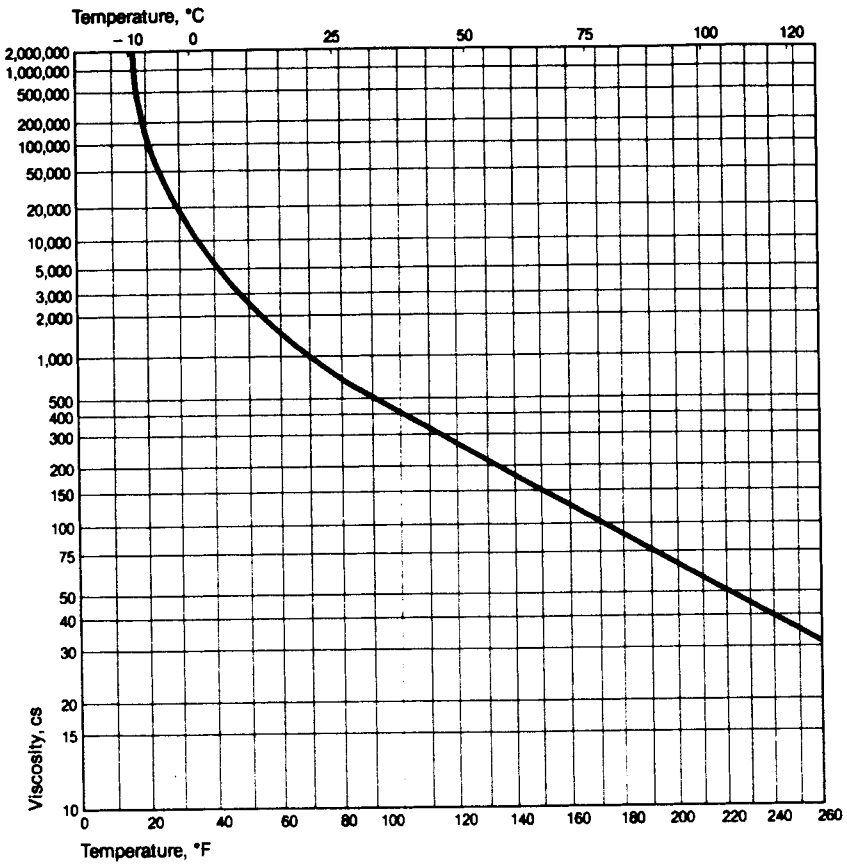
Acetaldehyde
Acetic Acid (glacial)
Acetic Anhydride
Acetone*
Acetylene Tetrabromide
Acrylonitrile
Allyl Alcohol
Allyl Bromide
Amyl Acetate
Amyl Alcohol
tert-Amyl Alcohol
Aniline
Benzaldehyde
Benzene
Benzyl Alcohol
Bromochloromethane
Bromocyclohexane
Bromoform
n-Butyl Acetate
n-Butyl Bromide
n-Butyl Lactate
n-Butyl Phosphate
n-Butylaldehyde
Carbon Bisulfide
Carbon Tetrachloride*
Castor Oil
o-Chloroaniline
Chloroform*
o-Chlorophenol
Cresol
Cyclohexanol
Cyclohexanone
Diacetone Alcohol
a-Diamylnaphthalene
Di-N-Butylamine
Dibutyl Sebacate
Dichloroacetic Acid
o-Dichlorobenzene
Dichloroethyl Ether
Dichloroisopropyl Ether
Diethylbenzene*
Diethylene Glycol*
Diethyl Ether
Diisopropylbenzene
1, 4-Dioxane*
Diphenyl Oxide*
Dipropylene Glycol*
Dodecyl Alcohol
Ethanol (95%)
Ethyl Acetate
Ethylbenzene*
Ethyl Bromide
Ethyl Chloroacetate
Ethyl Cyanoacetate
Ethyl Lactate
Ethylene Chlorohydrin
Ethylene Dibromide*
Ethylene Dichloride*
Ethylidene Dichloride
Furfural
Hydrochloric Acid (23°Be)*
Isophorone
Isopropanol (99%)
Isopropylbenzene
Isopropyl Bromide
Isopropyl Chloride
Lactic Acid (85%)
Lemon Oil
Mesityl Oxide
Methanol
Methyl Chloroform*
p-Methylcyclohexanol
Methylene Bromide
Methylene Chloride*
Methyl Ethyl Ketone
Methyl Formate
Methyl Isobutyl Carbinol
Methyl Isobutyl Ketone
Methyl Laurate
Methyl Salicylate*
a-Methylstyrene
Morpholine*
Nitrobenzene
Nitroethane
Nitromethane
1-Nitropropane
2-Nitropropane
Octyl Alcohol
Oleic Acid
Orange Oil
Paraldehyde
Pentachlorodiphenyl Oxide
Perchloroethylene*
Phenyl Ethyl Acetate
Phenyl Ethyl Alcohol
Phenetole
Phenyl Acetate
4-Phenyl-M-Dioxane
Pine Needle Oil
Piperidine
Polyglycol E200*
Polyglycol E300*
Polyglycol E400*
Polyglycol E600*
n-Propanol
Propylene Dibromide
Propylene Dichloride*
Propylene Glycol*
Pyridine
Ricinoleic Acid
Sperm Oil
Styrene Oxide
Tetrachloroethane
Tetrahydrofurfuryl Alcohol
Tetrahydronaphthalene
Triacetin
Tributyl Aconitate
1,1,2-Trichloroethane*
Trichloroethylene*
Triethylbenzene
Triethylene Glycol*
Trimethylene Bromide
Trimethylene Chlorobromide
Tripropylene Glycol*
Xylene

*Products of The Dow Chemical Company

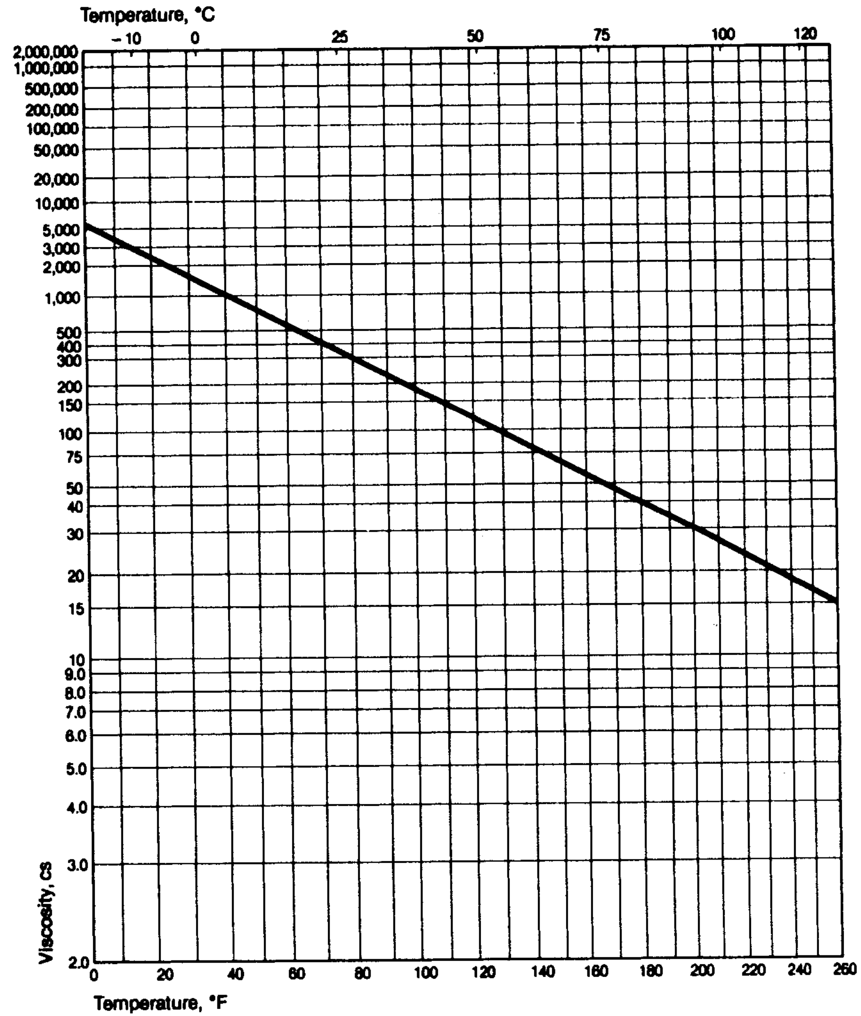
(continued)

Table 11.73: (continued)

Viscosity vs. Temperature For Polyglycol 112-2



Viscosity vs. Temperature For Polyglycol EP530



POLYOLS

Table 11.74: Properties of PLURONIC and TETRONIC Block Copolymer Surfactants *(47)*

PLURONIC® Block Copolymer Surfactants

Product	Form	Cloud Point (1% aqueous sol.)° C	Surface Tension (0.1%, 25° C) dynes/cm	Foam Height (Ross Miles, 0.1%, 50° C) mm	HLB[a] Value, 25° C
L10	Liquid	32	40.6	30	12—18
L31	Liquid	37	46.9	2	1—7
L35	Liquid	73	48.8	25	18—23
F38	Solid	>100	52.2	35	>24
L43	Liquid	42	47.3	0	7—12
L44, L44NF	Liquid	65	45.3	25	12—18
L61	Liquid	24	Ins.	0	1—7
L62	Liquid	32	42.8	25	1—7
L62D	Liquid	35	43.0	3	1—7
L62LF	Liquid	28	38.6	5	1—7
L64	Liquid	58	43.2	40	12—18
P65	Paste	82	46.3	70	12—18
F68, F68NF	Solid	>100	50.3	35	>24
F68LF	Solid	32	43.7	16	>24
F77	Solid	>100	47.0	100	>24
L81	Liquid	20	Ins.	Ins.	1—7
P84	Paste	74	42.0	90	12—18
P85	Paste	85	42.5	70	12—18
F87, F87NF	Solid	>100	44.0	80	>24
F88	Solid	>100	48.5	80	>24
L92	Liquid	26	35.9	15	1—7
F98	Solid	>100	43.0	40	>24
L101	Liquid	15	Ins.	Ins.	1—7
P103	Paste	86	34.4	40	7—12
P104	Paste	81	33.1	50	12—18
P105	Paste	91	39.1	40	12—18
F108, F108NF	Solid	>100	41.2	40	>24
L121	Liquid	14	33.0[b]	Ins.	1—7
L122	Liquid	19	33.0	20	1—7
P123	Paste	90	34.1	45	7—12
F127, F127NF	Solid	>100	40.6	40	18—23
10R5	Liquid	69	50.9	10	12—18
17R2	Liquid	35	41.9	0	2—7
17R4	Liquid	46	44.1	0	7—12
25R2	Liquid	29	37.5	1	2—7
25R4	Liquid	40	40.9	25	7—12
25R8	Solid	45	46.1	15	12—18
31R1	Liquid	25	34.1	0	1—7

[a] HLB calculated from glc relative retention ratios except for PLURONIC R series estimated ranges [b] Not completely soluble Ins. = Insoluble

TETRONIC® Block Copolymer Surfactants

Product	Form	Cloud Point (1% aqueous sol.)° C	Surface Tension (0.1%, 25° C) dynes/cm	Foam Height (Ross Miles, 0.1%, 50° C) mm	HLB[a] Value, 25° C
304	Liquid	75	53.0	2	12—18
701	Liquid	18	36.1[b]	0[b]	1—7
704	Liquid	79	40.3	80	12—18
901	Liquid	20	36.2[b]	0[b]	1—7
904	Liquid	74	35.4	70	12—18
908	Solid	>100	45.7	40	>24
1107	Solid	>100	42.9	50	>24
90R4	Liquid	43	42.7	20[b]	1—7
150R1	Liquid	20	33.3[b]	Ins	1—7

[a] HLB calculated from glc relative retention ratios [b] Not completely soluble Ins. = Insoluble

GLYCERINE ETHERS

Table 11.75: Glyceryl α-Monomethyl Ether *(2)*

α-Monomethyl Ether of Glycerine	$CH_3OCH_2CHOHCH_2OH$

Glyceryl α-monomethyl ether is a colorless liquid, soluble in benzene, ethyl alcohol, glycerol and water but insoluble in gasoline and carbon tetrachloride. It is a solvent for rosin, and when mixed with butyl acetate is compatible with nitrocellulose. It may be used as a selective solvent and in the manufacture of alkyd resins.

Boiling range at 745 mm	90% between 215-220°C
Refractive index, $n_D^{25°}$	1.442
Specific gravity at 25/25°C	1.1147
Weight per gal	9.29 lb

Table 11.76: Glyceryl α,γ-Dimethyl Ether *(2)*

α,γ-Dimethyl Ether of Glycerine	$H_3COCH_2CHOHCH_2OCH_3$

Glycerine α,γ-dimethyl ether is a water-white liquid soluble in benzene, gasoline, carbon tetrachloride, ethyl alcohol, water and glycerine, but insoluble in linseed oil and other fixed oils. It is a solvent for rosin, cellulose acetate and when mixed with butyl acetate is compatible with nitrocellulose. It has use as a solvent and plasticizer.

Boiling range at 736 mm.	90% between 164-170°C
Specific gravity at 25/25°C	1.003
Weight per gal	8.36 lbs

Table 11.77: Glyceryl α-Mono-n-Butyl Ether *(2)*

α-Mono-n-Butyl Ether of Glycerine	$C_4H_9OCH_2CHOHCH_2OH$

α-Mono-n-butyl ether of glycerine is a colorless liquid, soluble in benzene, gasoline, ethyl alcohol and carbon tetrachloride, but only slightly soluble in water and glycerol. It is a solvent for rosin and ester gum and may be used in the preparation of varnishes made with these substances.

Boiling range at 18 mm.	90% between 133-137°C
Refractive index, $n_D^{25°}$	1.434
Specific gravity at 25/25°C	0.945
Weight per gal	7.87 lbs

Table 11.78: Glyceryl α-Monoisoamyl Ether *(2)*

α-Monoisoamyl Ether of Glyceryl	$C_5H_{11}OCH_2CHOHCH_2OH$

α-Monoisoamyl ether of glyceryl is a colorless liquid which generally contains small amounts of other amyl isomers. It is soluble in benzene, ethyl alcohol, halogenated hydrocarbons, carbon tetrachloride, gasoline, linseed oil, and other fixed oils and, in certain amounts, soluble in glycerol and water. It is a solvent for rosin and, when mixed with butyl acetate, is compatible with nitrocellulose. It may be used as a solvent in the preparation of alkyd resins and in the synthesis of ester derivatives.

Boiling range at 745 mm	90% between 252-260°C
Refractive index, $N_D^{25°}$	1.442
Specific gravity at 25/25°C	0.987
Weight per gal	8.22 lbs

Table 11.79: Glyceryl α,γ-Diisoamyl Ether *(2)*

α,γ-Diisoamyl Ether of Glycerine $C_5H_{11}OCH_2CHOHCH_2OC_5H_{11}$

Glyceryl α,γ-diisoamyl ether is a water-white liquid which may contain small quantities of other amyl isomers. It is soluble in ethyl alcohol, benzene, gasoline, carbon tetrachloride and linseed oil, but insoluble in water and glycerol. It is a solvent for ester gum and rosin and has use as a solvent and plasticizer.

Boiling range at 10 mm	90% between 147–153°C
Refractive index, $n_D^{25°}$	1.432
Specific gravity at 25/25°C	0.903
Weight per gal	7.52 lbs

Table 11.80: Miscellaneous Glycerine Ethers *(2)*

Glycerine ethers range widely from low-boiling liquids to high-boiling solids. The solubility varies equally from complete water miscibility to complete water insolubility. The following lists these glyceryl ethers with their density and boiling points.

Glyceryl-Ether	d	b.p. (or m.p.) °C.
α-Isoamyl	0.987^{25}_{25}	$137\text{-}9_{27}$
		$251\text{-}2_{760}$
α, γ—di-Isoamyl	0.903^{25}_{25}	$147\text{-}53_{10}$
		269
α-Benzyl	1.196^{15}_{15}	$124\text{-}6_{2}$
α-n—Butyl	0.945^{25}_{25}	$133\text{-}7_{18}$
Cresyl		
α-Ethyl	1.063	$231\text{-}2_{760}$
α, γ-di-Ethyl	0.920_{21}	190
tri-Ethyl	0.886^{25}_{4}	$103\text{-}5_{60}$
		181_{760}
Epiethylin	0.94_{12}	128-9
Glycidol	1.1143_{25}	41_{1}
α-Methyl	1.1147^{25}_{25}	110_{13}
		221_{754}
β-Methyl		
α, γ-di-Methyl	1.003^{25}_{25}	$69.5\text{-}70.5_{15}$
		$164\text{-}70_{736}$
tri-Methyl	0.937^{25}_{4}	148_{763}
Epimethylin	1.002_{4}	$113\text{-}4_{770}$
mono-α-Naphthyl		m.p. 91-2
mono-β-Naphthyl		m.p. 109-10
α-Phenyl		$185\text{-}7_{15}$
		$150\text{-}5_{4}$
		m.p. 53-4
α, γ-di-Phenyl		287-8
		m.p. 80-1
α-o-Cl-Phenyl		m.p. 56
α-p-Cl-Phenyl		m.p. 76
mono-2, 4-di-Nitrophenyl		m.p. 83
Epiphenylin	1.08^{25}_{4}	$115\text{-}6_{3\text{-}4}$
α-Propyl	1.074^{18}_{4}	$118\text{-}22_{15}$
α, γ-di-Isopropyl	0.915_{15}	112-3
α, γ-di-n-Propyl		215–7
mono-p-Tolyl		m.p. 73-4

Ketones

ACETONE

Dimethyl Ketone, Methylacetyl, Propanone-2 $CH_3{-}CO{-}CH_3$

Acetone is a colorless, limpid, mobile, hygroscopic, flammable liquid having a mint-like odor.

Table 12.1: Physical Properties of Acetone *(41)*

Typical Properties

Molecular Weight	58.08	Boiling Range, 760 mm, °C	
Color (Pt-Co Scale), max	5	Initial Boiling Point, min	55.1
Weight/Vol, 20°C,		Dry Point, max	57.1
lb/gal (U. S.)	6.59	Freezing Point, °F (°C)	−138 (−95)
kg/litre	0.79	Flash Point, Tag Closed Cup, °F (°C)	−4 (−20)
lb/gal (Imperial)	7.91	Tag Open Cup, °F (°C)	−2 (−19)
Solubility, 20°C, wt %		Fire Point, °F (°C)	−2 (−19)
In water	Complete	Flammable Limits in Air, % by volume	
Water in	Complete	Lower	2.6
Evaporation Rate (n-butyl acetate = 1)	7.7	Upper	12.8
Dilution Ratio, toluene	4.6	Autoignition Temperature (ASTM D-2155),	
VM & P naphtha	0.55	°F (°C)	1000 (538)
Refractive Index, 20°C	1.3589	NFPA Classification 30	IB
Vapor Pressure, 20°C, mm Hg	180	DOT Classification	Flammable Liquid
Specific Gravity 20°/20°C	0.792	DOT Labels Required	Flammable Liquid

Table 12.2: Low Temperature Characteristics of Aqueous Solutions of Acetone *(19)*

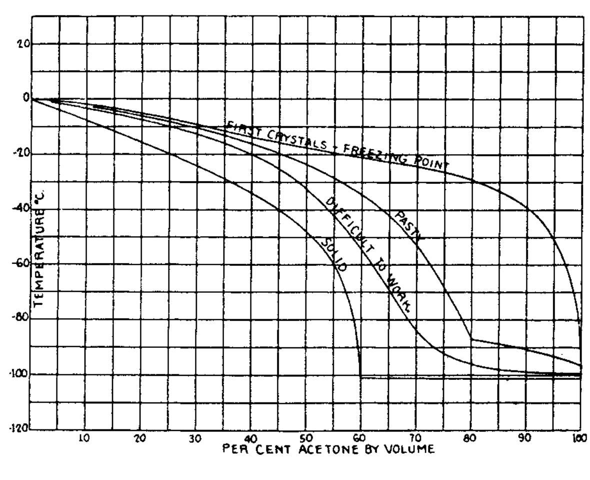


Table 12.3: Solubility of Various Materials in Acetone *(44)*

Solubility of Shellacs in Acetone

Type	Per cent soluble at boiling point of acetone
Superfine orange shellac	98.8
Superfine shellac	92.8
T. N. shellac, No. 1	95.6
T. N. shellac, No. 2	98.8
A. C. garnet	81.3
Refus lac	63.0

Percentage of Acetone-insoluble Matter in Various Resins

Type	Per cent insoluble in acetone
Kauri, pale	8.90
Kauri, brown	38.70
Kauri, bush	20.70
Rosin	Soluble
Burgundy pitch	Soluble
Stockholm tar	Soluble
Mastic	9.50
Sandarac	Soluble
Madagascar copal, fused	84.80

Solubility of Fats, Oils and Greases in Acetone

Type	Miscibility a 25°C.	Per cent soluble at 25°C.	Solubility at boiling point of acetone
Chinawood oil	M		
Coconut oil (refined and bleached)	M		
Corn oil (raw)	M		
Cottonseed oil (refined and bleached)	M		
Cottonseed oil (hydrogenated, Crisco)	M	100.0	M
Cottonseed oil (hydrogenated)		32.0	M
Cottonseed oil (stearin)	M		
Cottonseed oil (summer)	M		
Cottonseed oil (winter)	M		
Fish oil (herring, raw)	M		
Fish oil (hydrogenated)		35.8	M
Fish oil (menhaden, raw)	m	99.8	M
Grease, brown	m	96.4	99.8
Grease, garbage	m	99.6	99.7
Grease, white	m	97.3	M
Linseed oil, raw	M		

M—miscible in all proportions.
m—part soluble at 25°C is miscible in all proportions.

Solubility of Copal Resins in Acetone

Type	Per cent soluble at boiling point of acetone	Solubility of part soluble at 25°C
Congo	40.8	M[1]
Manila, soft	96.6	M
Elemi	100.0	M
Yacca	96.6	M
Sandarac	97.0	M[1]
Sierra Leone	55.5	M[1]
Borneo pontianac	93.5	M[1]
Batavia dammar	88.7	M[1]
Red, accrodites	95.2	M

M—miscible in all proportions.
M[1]—miscible in concentrated solutions with separation on dilution.

Solubility of Water Gums in Acetone

Type	Per cent soluble at boiling point of acetone
Arabic gum	11.9
Indian gum	16.7
Senegal gum	12.0
Tragacanth, Allepa	9.2
Tragacanth, Persian	8.0
Tragacanth, Turkey	7.2

Solubility of Asphalts and Bitumens in Acetone

Type	Per cent soluble at boiling point of acetone
Alberite	5.8
Asphalt, blown, from mid-continental petroleum	56.4
Bermudez pitch, refined	62.4
Coal-tar pitch, refined	70.4
Fatty acid pitch, soft grade	62.4
Fatty acid pitch, medium grade	54.3
Gilsonite selex	25.0
Grahamite	1.6
Mexican petroleum asphalt, steam-distilled, medium grade	44.2
Mexican petroleum asphalt, steam-distilled, soft grade	64.3
Petroleum asphalt, steam-distilled, California, medium grade	81.0
Residual oil from Gulf Coast	61.0
Residual oil from steam distillation of mid-continental petroleum asphalt	97.2
Syrian asphalt	5.9
Trinidad pitch, refined	42.0

Table 12.4: Specific Gravity of Aqueous Solutions of Acetone at Different Temperatures *(19)*

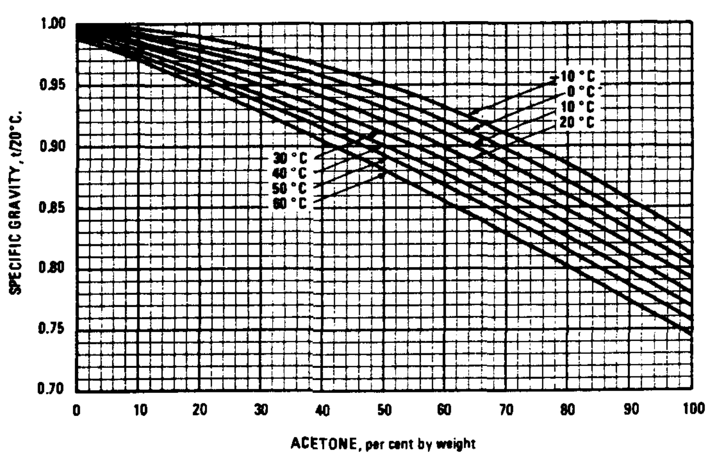


Table 12.5: Surface Tension of Aqueous Solutions of Acetone at 25°C *(19)*

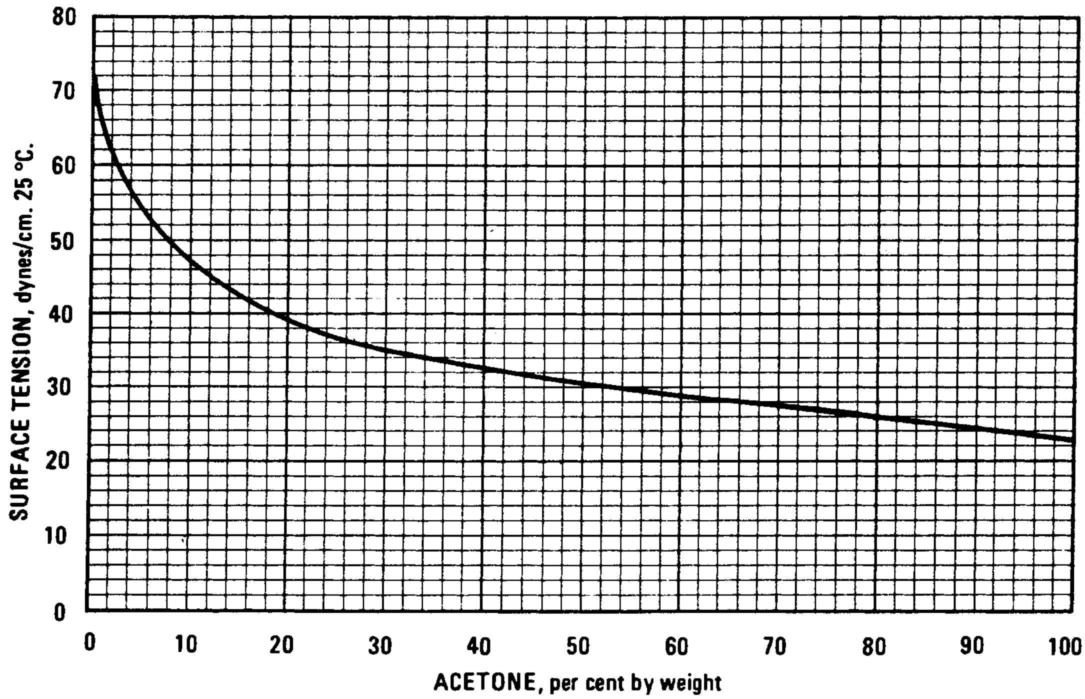


Table 12.6: Viscosity of Aqueous Acetone Solutions at 25°C *(19)*

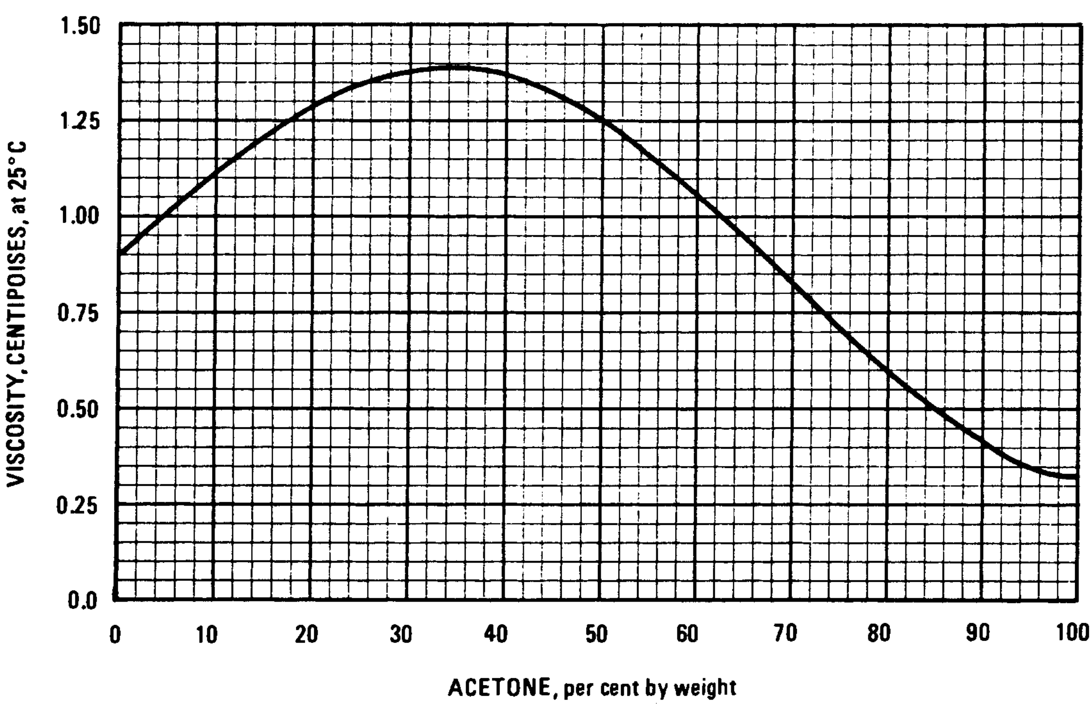


Table 12.7: Refractive Index of Aqueous Solutions of Acetone at 25°C *(19)*

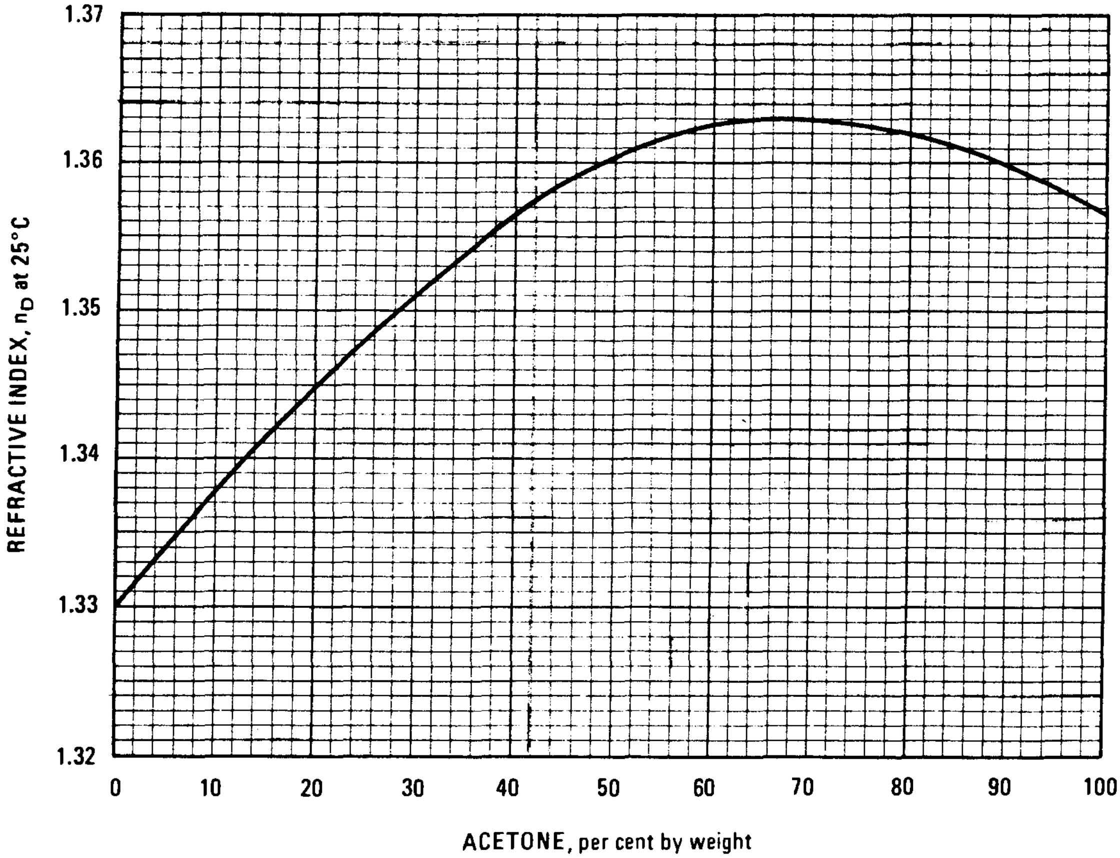


Table 12.8: Liquid-Vapor Equilibria for Aqueous Solutions of Acetone at Different Pressures *(19)*

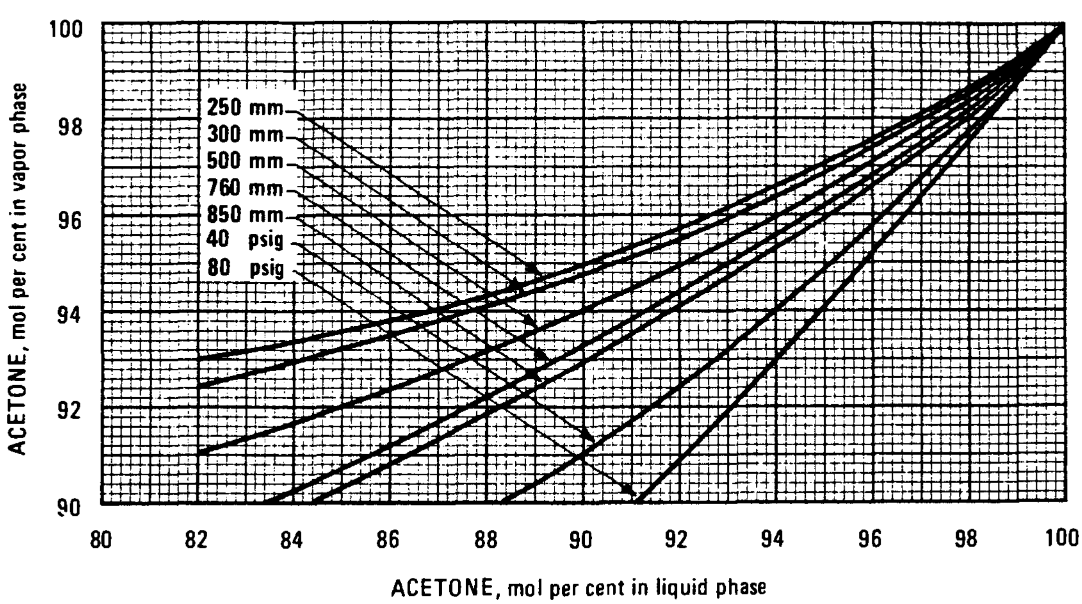
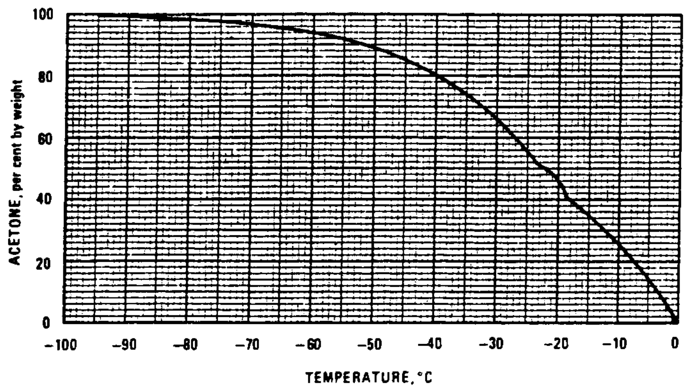


Table 12.9: Freezing Point of Aqueous Solutions of Acetone *(19)*



METHYL ETHYL KETONE

MEK, Butanone-2, Ethyl Methyl Ketone $CH_3—CO—C_2H_5$

Methyl ethyl ketone is a colorless, stable, mobile, flammable liquid with an odor like acetone.

Table 12.10: Physical Properties of Methyl Ethyl Ketone *(2)*

Azeotropic Mixtures

	% by wt.		% by wt.	B.P. (°C)
Methyl ethyl ketone	37.5	Benzene	62.5	78.4
	73	*tert*-Butyl alcohol	27	77.5
	84.7	Carbon disulfide	15.3	45.9
	29	Carbon tetrachloride	71	73.8
	40	1,3-Cyclohexadiene	60	73.0
	40	Cyclohexane	60	72.0
	12	Ethyl acetate	82	77.0
	60	Ethyl alcohol	40	74.8
	20	Ethyl sulfide	80	77.5
	70	Isopropyl alcohol	30	77.5
	52	Methyl propionate	48	79.3
	55	Propyl formate	45	79.5
	75	Propyl mercaptan	25	55.5
	45	Thiophene	55	76

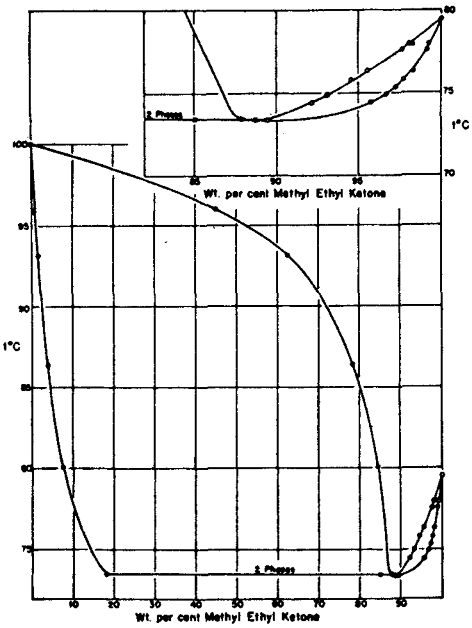
Ternary Mixtures

						B.P. (°C)
(1) Methyl ethyl ketone	22.2	Water	3.0	CCl_4	74.8	65.7
(2)	17.8		8.9	C_6H_6	73.8	68.9
Upper layer of (2)	19.0		0.4		80.6	
Lower layer of (2)	3.5		96.4		0.1	

Typical Properties and Specifications

Boiling point at 760 mm	79.6°C
Coefficient of expansion	0.00076 per °F
Electrical Conductivity	1.0×10^{-7} ohms at 25°C
Explosive limits	1.97%—10.2%
Flash point (Tag Closed Cup)	25°F
Freezing point	−86.4°C
Heat of combustion	582 Cal./mole
Latent heat of Vaporization at 20°C	106.0 cal./g
Refractive Index, N 20/D	1.3788
Solubility of water in solvent at 20°C	10% by wt.
Specific gravity at 20/20°C	0.805–0.807
Specific heat	0.55 cal./g
Surface tension	
0°C 26.9 dynes/sq cm	
20 24.6	
40 22.3	
75 18.4	
Viscosity at 15°C	0.00423 poise
Weight per gallon at 20°C	6.72 lbs.
Acidity (as acetic)	0.0025 by wt. (max.)
Distillation range (ASTM)	70°–80.5°C
Non-volatile matter	3 mg. per 100 ml. (max.)
Purity	99%

Table 12.11: Methyl Ethyl Ketone and Water *(14)*



Vapor and Liquid Compositions at the Boiling Point
Pressure = 1 Atm.

METHYL n-PROPYL KETONE

Pentanone-2 $CH_3{\cdot}CO{\cdot}CH_2{\cdot}C_2H_5$

Commercial methyl n-propyl ketone, produced synthetically by dehydrogenation of the corresponding alcohol, consists of a mixture of methyl n-propyl and diethyl ketones in the approximate ratio of 3 to 1, and contains at least 97% of these ketones, the balance being secondary amyl alcohol. It is a colorless liquid, soluble in alcohol and ether but only very slightly soluble in water.

Table 12.12: Properties of Methyl n-Propyl Ketone *(41)*

Typical Properties

Molecular Weight ($C_5H_{10}O$)	86.13	Specific Gravity at 20°/20° C	0.807
Branched-Chain Ketones, wt % (max)	10	Boiling Range at 760 mm, °C	
Color (Pt-Co Scale), max	15	Initial Boiling Point, min	101
Evaporation Rate (n-butyl acetate = 1)	2.3	Dry Point, max	105
Weight/Vol at 20° C		Freezing Point, °F (°C)	-122 (-86)
lb/gal (U.S.)	6.72	Flash Point, Tag Closed Cup, °F (°C)	46 (8)
kg/L	0.81	Tag Open Cup, °F (°C)	50 (10)
lb/gal (Imperial)	8.06	Fire Point, °F (°C)	50 (10)
Solubility at 20° C, wt %		Flammable Limits in Air, % by volume	
In water	3.1	Lower, at 94° F (34° C)	1.56
Water in	4.2	Upper, at 144° F (62° C)	8.7
Dilution Ratio, toluene	3.9	Autoignition Temperature (ASTM D 2155), °F (°C)	840 (449)
VM & P naphtha	1.0	NFPA Classification 30	IB
Refractive Index at 20° C	1.3904	DOT Classification	Flammable Liquid
Vapor Pressure at 20° C, mm Hg	27.8	DOT Labels Required	Flammable Liquid

(continued)

Table 12.12: (continued)

Comparison of Solvent Power
MPK vs Other Solvents

Solvent	Solution Viscosity at 25°C, cP (mPa · s)			
	RS ½-Sec Nitrocellulose 8%	CAB-381-0.5[a] 10%	*Elvacite* 2010 Acrylic[b] 10%	VYNS[c] 10%
Ethyl Acetate[a]	23	28.3	5.8	–
Isopropyl Acetate[a]	25	31.0	6.6	–
MEK	14	18.8	3.6	22.8
MPK[a]	16	20.8	4.5	31.5
MIBK[a]	23	27.0	5.8	59.2

[a]*an Eastman product*
[b]*product of Du Pont Company*
[c]*product of Union Carbide Corporation*

METHYL n-BUTYL KETONE

Hexanone-2 $CH_3 \cdot CO \cdot C_4H_9$

Methyl n-butyl ketone is a colorless liquid, freely soluble in alcohol and ether but very slightly soluble in water.

Table 12.13: Properties of Methyl n-Butyl Ketone *(41)*

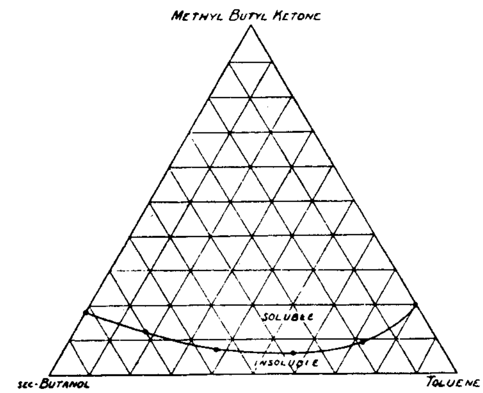
Molecular Weight ($C_6H_{12}O$)	100.16
Melting Point, °C	-56.9
Boiling Point, °C, 760 mm	127
Evaporation Rate (n-butyl acetate = 1)	1.0
Weight/Vol, at 20°C	
lb/gal. (U.S.)	6.75
kg/liter	0.81
lb/gal. (Imperial)	8.10
Solubility, 20°C, wt %	
In water	1.4
Water in	2.1
Dilution Ratio, toluene	4.0
VM & P naphtha	1.1
Color (Pt-Co Scale), ppm	5
Acidity, as acetic acid, wt %	0.01
Water, wt %	0.05
Branched-Chain Ketones, max, wt %	5
Refractive Index, 20°C	1.3969
Flash Point (Tag Closed Cup), °F (°C)	77 (25)
(Tag Open Cup), °F (°C)	83 (28)
Fire Point, °F (°C)	86 (30)
Flammable Limits in Air, % by volume	
Lower	1.3
Upper	8.0
Autoignition Temperature (ASTM D-2155), °F (°C)	795 (424)
NFPA Classification 30:	Flammable Liquid, Class IC
ICC Labels Required	None
Bureau of Explosives Classification	Nonhazardous Liquid

Several of the solvent characteristics of Methyl n-Butyl Ketone are listed in the following table. Similar values for other solvents are included for comparison.

Eastman Solvent	Evap. Rate	Blush Res., % R.H. @ 80°F (27°C)	Solution Viscosity, 25°C, cp		
			RS. ½-Sec Cellulose Nitrate[a] 10 Wt %	*Exon*[b] 470 20 Wt %	*Elvacite*[c] 2010 20 Wt %
Methyl n-Butyl Ketone	1.0	80	28	24	65
Methyl Isobutyl Ketone	1.6	78	30	24	64
Isobutyl Acetate	1.4	80	49	38	83
n-Butyl Acetate	1.0	83	46	33	77

[a]*product of Hercules, Inc.*
[b]*product of Firestone Plastics Co.*
[c]*product of E. I. du Pont de Nemours Co., Inc.*

Table 12.14: Solubility of Dry Half-Second R.S. Nitrocellulose in a System of Methyl Butyl Ketone-sec-Butanol-Toluene *(2)*



METHYL ISOBUTYL KETONE

Hexone, 4-Methylpentanone-2, 2-Methyl-4-Pentanone $CH_3 \cdot CO \cdot C_4H_9$

Although first prepared in 1849, methyl isobutyl ketone was not made synthetically and on a large scale until the last decades. It is a stable, colorless liquid classified as a medium boiler. It is miscible with most organic solvents and with mineral and vegetable oils. When compared with butyl acetate its rate of evaporation is somewhat faster so that it can either replace esters or be combined with them. Its rate of evaporation is somewhat faster than that of butyl acetate. It is used in the vinyl type resins for coatings where it helps to prevent gelling and lowers viscosity, in nitrocellulose lacquer manufacture, in extraction processes and in chemical synthesis. It may be used in dewaxing oils.

Table 12.15: Properties of Methyl Isobutyl Ketone *(41)*

Typical Properties

Molecular Weight ($C_6H_{12}O$)	100.16
Color (Pt-Co Scale), max	10
Weight/Vol at 20°C,	
lb/gal (U.S.)	6.67
kg/L	0.80
lb/gal (Imperial)	8.00
Solubility at 20°C, wt %	
In water	2.0
Water in	1.0
Evaporation Rate (n-butyl acetate = 1)	1.6
Dilution Ratio, toluene	3.5
VM & P naphtha	1.0
Refractive Index at 20°C	1.3958
Vapor Pressure at 20°C, mm Hg	15
Specific Gravity at 20°/20°C	0.802
Boiling Range at 760 mm, °C	
Initial Boiling Point, min	114
Dry Point, max	117
Freezing Point, °F (°C)	-119 (-84)
Flash Point, Tag Closed Cup, °F (°C)	60 (16)
Tag Open Cup, °F (°C)	68 (20)
Fire Point, °F (°C)	70 (21)
Flammable Limits in Air, % by volume	
Lower, at 200°F (93°C)	1.22
Upper, at 200°F (93°C)	7.96
Autoignition Temperature (ASTM D-2155), °F (°C)	840 (449)
NFPA Classification 30	IB
DOT Classification	Flammable Liquid
DOT Labels Required	Flammable Liquid

(continued)

Table 12.15: (continued)

Several of these solvent characteristics of MIBK are listed in the following table. Similar values for other solvents are included for comparison.

Eastman Solvent	Evap Rate	Blush Res., % R.H. @ 80°F (27°C)	Solution Viscosity at 25°C, cP (mPa•s)		
			RS ½-Sec Cellulose Nitrate[a] 10 Wt %	*FPC* 470 Resin[b] 20 Wt/%	*Elvacite* 2010 Resin[c] 20 Wt/%
Methyl Isobutyl Ketone	1.6	78	30	24	64
Isobutyl Acetate	1.4	80	49	38	83
n-Butyl Acetate	1.0	83	46	33	77

[a]*Product of Hercules Incorporated*
[b]*Product of Firestone Plastics Company*
[c]*Product of Du Pont Company*

Table 12.16: Solubility of Miscellaneous Materials in Methyl Isobutyl Ketone at 20° to 25°C *(2)*

Soluble, Over 5% by Weight Concentration

Acid	Gums
Oleic (Technical Red Oil)	Elemi
	Kauri (Pale Bold)
Oils	Mastic
Castor, Refined Raw	Pontianak
Cottonseed, Raw	
China Wood	Resins, Natural
Coconut, Crude	Dammar (dewaxed)
Fish, Processed	Batavia
Linseed, Pure Raw	Singapore
Mineral, 70/80 viscosity	Light Rosin
Pine	Sandarac
Soybean, 2-3 viscosity	

RESINS, SYNTHETIC

Trade Name	Type
Amberlac 80-X	Modified drying type phthalic alkyd
Amberol 801	Rosin modified maleic alkyd
Arochem 519	Modified maleic
Aroclor 1260	Chlorinated diphenyl
Bakelite BR-254	Non-heat-hardening 100% para-phenylphenol resin
No. 1 Solid Beckosol	Phenolic modified drying type alkyd
Beckosol 1313	Drying type alkyd
Beetle 227-8	Unmodified urea-formaldehyde
Cellolyn 102	Modified rosin ester
Ester gum	Rosin ester
Ethyl methacrylate	Acrylic ester
Glyptal 2477	Non-drying type alkyd
Melmac 245-8	Unmodified melamine-formaldehyde
Neville R-21 (soft)	Unmodified coumarone-indene
Nevillite 1	Naphthene polymers
Nitrocellulose	Cellulose ester
Parlon X (20 cps.)	Chlorinated rubber
Phenac 608	Modified phenolic
Santolite K	Alkyl-arylsulfonamide-formaldehyde
Saran F-120	Vinylidenechloride-acrylonitrilecopolymers
Staybelite	Hydrogenated rosin ester
Teglac Z-152	Rosin modified maleic alkyd
Vinylite AYAF	Polyvinyl acetate
Vinylite VMCH	Maleic modified vinyl chloride-vinyl acetate copolymers
Vinylite VYHH	Vinyl chloride-vinyl acetate copolymers

METHYL n-AMYL KETONE

Heptanone-2 $CH_3(CH_2)_4 \cdot CO \cdot CH_3$

This ketone is a colorless, stable liquid, miscible with most lacquer solvents and only very slightly soluble in water. It is used as a high-boiling solvent for nitrocellulose and is particularly applicable in vinyl resin finishes, where its slow rate of evaporation prevents quick drying, improves the flow and gives blush resistance; also used with some effect in insecticidal preparations.

Table 12.17: Properties of Methyl n-Amyl Ketone *(41)*

Typical Properties

Molecular Weight ($C_7H_{14}O$)	114.19	Specific Gravity at 20°/20°C	0.817
Branched-Chain Ketones, wt % max	2.0	Boiling Range at 760 mm, °C	
Color (Pt-Co Scale), max	10	Initial Boiling Point, min	149
Evaporation Rate (n-butyl acetate = 1)	0.4	Dry Point, max	153.5
Weight/Vol. at 20°C		Freezing Point, °F (°C)	−27 (−33)
lb/gal (U. S.)	6.80	Flash Point, Tag Closed Cup, °F (°C)	102 (39)
kg/L	0.81	Tag Open Cup, °F (°C)	114 (46)
lb/gal (Imperial)	8.16	Fire Point, °F (°C)	115 (46)
Solubility at 20°C, wt %		Flammable Limits in Air, % by volume	
In water	0.46	Lower, at 150°F (66°C)	1.11
Water in	1.31	Upper, at 250°F (121°C)	7.9
Dilution Ratio, toluene	3.9	Autoignition Temperature (ASTM D 2155), °F (°C)	740 (393)
VM & P naphtha	1.2	NFPA Classification 30	II
Refractive Index at 20°C	1.4085	DOT Classification	Combustible Liquid
Vapor Pressure at 20°C, mm Hg	2.14	DOT Labels Required	None

COMPARISON OF PROPERTIES OF HIGH-BOILING SOLVENTS

Solvent	Evap. Rate	Blush Res., % R.H. @ 80°F (27°C)	Solution Viscosity at 25°C, cP		
			RS ½-Sec Cellulose Nitrate[a] 10 Wt %	CAB-381-0.5[b] 10 Wt %	VMCH Copolymer[c] 20 Wt %
Methyl n-Amyl Ketone[b]	0.4	93	40	37	158
Methyl Isoamyl Ketone[b]	0.5	89	42	37	164
Isobutyl Isobutyrate[b]	0.4	92	128	Insol	Gel
Ethyl Amyl Ketone	0.3	94	69	Insol	320
Diisobutyl Ketone[b]	0.2	95	143	Insol	Gel
Ektasolve® EE Acetate[b]	0.2	94	113	89	1040

[a]product of Hercules Incorporated *[b]an Eastman product* *[c]product of Union Carbide Corporation*

METHYL ISOAMYL KETONE

MIAK $CH_3—CO—C_5H_{11}$

MIAK is a retarder solvent, having an evaporation rate of 0.5, but it also possesses exceptional solvent power for most film-formers. In lacquers, the low evaporation rate of MIAK promotes good flow and leveling properties; whereas the high solvency provides low viscosities or permits a higher nonvolatile content.

Table 12.18: Properties of Methyl Isoamyl Ketone *(41)*

Typical Properties

Molecular Weight ($C_7H_{14}O$)	114.19	Boiling Range, 760 mm, °C	
Color (Pt-Co Scale), max	10	Initial Boiling Point, min	141
Weight/Vol, 20°C,		Dry Point, max	148
lb/gal (U. S.)	6.76	Freezing Point, °F (°C)	-101 (-74)
kg/litre	0.81	Flash Point, Tag Closed Cup, °F (°C)	96 (36)
lb/gal (Imperial)	8.14	Tag Open Cup, °F (°C)	106 (41)
Solubility, 20°C, wt %		Fire Point, °F (°C)	107 (42)
In water	0.5	Flammable Limits in Air, % by volume	
Water in	1.2	Lower, at 200°F (93°C)	1.05
Evaporation Rate (n-butyl acetate = 1)	0.5	Upper, at 200°F (93°C)	8.2
Dilution Ratio, toluene	4.1	Autoignition Temperature (ASTM D-2155), °F (°C)	795 (425)
VM & P naphtha	1.2	NFPA Classification 30	IC
Refractive Index, 20°C	1.4069	DOT Classification	Flammable Liquid
Vapor Pressure, 20°C, mm Hg	4.5	DOT Labels Required	Flammable Liquid
Specific Gravity, 20°/20°C	0.814		

(continued)

Table 12.18: (continued)

Solvent	Evap. Rate	Blush Res., % R. H. @ 80°F (27°C)	Solution Viscosity, 25°C, cP		
			RS ½-Sec Cellulose Nitrate[a] 10 Wt/%	*FPC* 470 Resin[b] 20 Wt/%	*Elvacite* 2010 Resin[c] 20 Wt/%
Methyl Amyl Acetate	0.5	92	128	Insol	Insol
Methyl Isoamyl Ketone	0.5	89	42	34	68
Isobutyl Isobutyrate	0.4	92	128	Insol	Insol
Ektasolve® EE Acetate	0.2	94	113	Insol	284

[a]*product of Hercules Incorporated*
[b]*product of Firestone Plastics Company*
[c]*product of Du Pont Company*

Table 12.19: Properties of Methyl Isoamyl Ketone vs Other Solvents *(41)*

Solvent	Evaporation Rate	Dilution Ratio (Toluene)	Blush Resistance, % R.H. at 80°F.	Specific Gravity, 20/20°C.	Flash Point, Tag Open Cup, °F.	Boiling Range, 760 mm., °C.
Methyl isobutyl ketone	1.6	3.6	78	0.8018	73	114-117
Isobutyl acetate	1.4	2.7	78	0.8728	90	114-118
n-Butyl acetate	1.0	2.7	82	0.8109	100	116-118
Amyl acetate	0.6	2.4	92	0.862	93	100-150
MIAK	**0.50**	**4.1**	**92**	**0.813**	**110**	**141-148**
Methyl amyl acetate	0.5	1.7	92	0.8595	110	143-150
2-Ethoxyethanol	0.3	4.9	65	0.9311	130	132-136
4-Methoxy-4-methyl-pentanone-2	0.3	3.1	91	0.904	141	147-163
Ethyl amyl ketone	0.2	2.2	94	0.822	135	156-162
2-Ethoxyethyl acetate	0.2	2.5	91	0.9748	150	145-165
4-Methoxy-4-methyl-pentanol-2	0.2	4.7	93	0.890	140	164-169
Cyclohexanone	0.2	5.8	92	0.945	129	153-160
2-Butoxyethanol	0.06	3.33	96	0.9019	165	166-173
Isophorone	0.03	6.2	97	0.9229	205	205-220

Table 12.20: Butyrate-Acrylic Wood Lacquer—Substituting Isoamyl Ketone for 2-Ethoxyethyl Acetate *(41)*

Ingredients	Part A Wt. %		Part B Wt. %
Half-Second Butyrate	8.5		8.5
Acryloid B-66 resin (40%)[1]	21.3		21.3
Santicizer 160 plasticizer[2]	3.0		3.0
Dow-Corning 510 (1000 cs.) fluid[3]	0.01		0.01
Eastman Inhibitor DOBP[4]	0.09		0.09
Toluene	26.3		36.3
Isobutyl acetate	13.6		13.6
Isobutyl alcohol	13.6		3.6
Methyl ethyl ketone	6.8		6.8
MIAK	6.8	—	6.8
2-Ethoxyethyl acetate	—	6.8	—
	100	100	100
Solids, %	20.12	20.12	20.12
Viscosity, cp.	45	50	42
Wt./gal., lb.	7.45	7.51	7.50
Flow out	excellent	excellent	excellent

[1]Product of Rohm and Haas Company
[2]Product of Monsanto Chemical Company
[3]Product of Dow Corning Corporation
[4]2-Hydroxy-4-dodecyloxy benzophenone

METHYL HEXYL KETONE

Octanone-2 — $CH_3(CH_2)_5CO \cdot CH_3$

A colorless liquid with a characteristic odor, methyl hexyl ketone is used as a solvent for vinyl compounds and dyes, and has been found particularly suitable in dispersing dyes in light petroleum oils for newsprint inks.

Table 12.21: Properties of Methyl Hexyl Ketone *(2)*

Purity	95%, min.
Specific gravity at 20°C.	0.81-0.83
Weight per gallon at 20°C.	6-8 lbs.

METHYL HEPTYL KETONE

MHK
5-Methyl-2-Octanone

$CH_3\underset{\|}{\overset{}{C}}CH_2CH_2\underset{|}{C}HCH_2CH_2CH_3$ (C=O at C-2; CH_3 at C-5)

Methyl heptyl ketone, a high-boiling, active solvent, imparts desirable drying characteristics in many high-temperature baked coatings.

Table 12.22: Properties of Methyl Heptyl Ketone *(41)*

Molecular Weight ($C_9H_{18}O$), calcd	142.24	Color (Pt-Co Scale), ppm	5-25
Melting Point, °C	-9	Acidity, as acetic acid, wt %	0.018
Boiling Range, °C, 760 mm	183-195	Water, wt %	0.01-0.05
Evaporation Rate (n-butyl acetate = 1)	0.08	Flash Point (Tag Closed Cup), °F (°C)	140 (60)
Weight/Vol, at 20°C		(Tag Open Cup), °F (°C)	160 (71)
lb/gal (U.S.)	6.87	Fire Point, °F (°C)	168 (76)
kg/liter	0.83	Flammable Limits in Air, % by volume	
lb/gal (Imperial)	8.59	Lower (at 180°F)	0.9
Solubility, 20°C, wt %		Upper (at 313°F)	5.9
In water	0.5	Autoignition Temperature (ASTM D-2155), °F (°C)	680 (360)
Water in	0.95	NFPA Classification 30:	Combustible Liquid,
Dilution Ratio, toluene	3.0		Class IIIA
VM & P naphtha	1.0	ICC Labels Required	None
Refractive Index, 20°C	1.422	Bureau of Explosives Classification	Nonhazardous Liquid

Solvent	Evap Rate	Dilution Ratio		Blush Res., % RH @ 80°F (27°C)	Sp Gr 20°/20°C	Lb/gal @20°C
		Toluene	VM & P Naphtha			
MAK	0.4	3.9	1.2	93	0.815	6.80
EKTASOLVE® *EB* Solvent*	0.1	3.4	2.1	96	0.902	7.51
MHK	0.08	3.0	1.0	97	0.827	6.87
Isophorone	0.03	6.2	1.2	97	0.922	7.68

**EKTASOLVE EB (ethylene glycol monobutyl ether) is an Eastman product.*

ETHYLBUTYL KETONE

Heptanone-3 $C_2H_5COCH_2CH_2CH_2CH_3$

Ethylbutyl ketone is a stable, high-boiling solvent of special value in lacquers and synthetic resin coatings. Its evaporation rate in relation to those of comparable solvents is indicated in the following tabulation:

Solvent	Hours
Methyl isobutyl ketone	4.5
Butyl acetate	8
Ethylbutyl ketone	14
Amyl acetate	16
Methylamyl acetate	17
Methylamyl ketone	20
"Cellosolve" acetate	38
Diisobutyl ketone	44

The unusual combination of good solvent power with medium evaporation rate makes ethylbutyl ketone generally useful for coating solutions having adequate flow without unduly long drying time. It bakes out of films somewhat faster than other comparable ketones.

Table 12.23: Properties of Ethylbutyl Ketone *(2)*

Boiling point	147.8°C.
Freezing point	-36.7°C.
Coefficient of expansion at 20°C.	0.00107
Flash point	125°F.
Solubility in water at 20°C.	0.43% by wt.
Solubility of water in at 20°C.	0.78% by wt.
Refractive index at 20°C.	1.4085
Specific gravity at 20/20°C.	0.8197

ETHYL AMYL KETONE

EAK, 5-Methyl-3-Heptanone

$$CH_3CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2\overset{\overset{\displaystyle CH_3}{|}}{C}HCH_2CH_3$$

Ethyl amyl ketone, a high boiling ketone, is a colorless, stable liquid with a mild pleasant odor. It is compatible with alcohols, ethers, other ketones and organic liquids, and in addition, exhibits low water miscibility. Ethyl amyl ketone's high solvency for cellulose esters, vinyl polymers and copolymers, synthetic and natural protective coating resins, coupled with its slow evaporation rate, high blush resistance and good diluent tolerance makes it a valued surface coating raw material.

Table 12.24: Properties of Ethyl Amyl Ketone *(14)*

Apparent specific gravity, 20/20°C	0.820-0.824
25/25°C	0.816-0.820
Color, Pt-Co, Max	25
Distillation range, °C	156-162
Acidity (as acetic acid), % w, Max	0.01
Water, % w, Max	0.15
Alcohol (as ethyl amyl carbinol), % w, Max	0.50

DI-n-PROPYL KETONE

Heptanone-4, Butyrone, Amyl Ketone $(CH_3CH_2CH_2)_2CO$

Di-n-propyl ketone is a colorless, stable liquid having a pleosant odor. It is miscible with many organic solvents, and dissolves a wide variety of materials, some of which are crude rubber, nitrocellulose, raw and blown oils, many natural and synthetic resins like dewaxed dammar, manila, rosin, ester gum, and waxes.

Table 12.25: Properties of Di-n-Propyl Ketone *(2)*

Boiling point	143.7°C.
Coefficient of expansion	0.001073 (per °C.) to 20°C.
	0.001115 (per °C.) to 55°C.
Dilution ratio ("Kemsolene")	0.8
(Toluene)	3.1
Flash point (ASTM Open Cup)	49°C.
Freezing point	-32.1°C.
Heat of combustion	1051 cal./mol
Latent heat of vaporization	75.8 cal./g.
Solubility in water at 20°C.	0.53% by wt.
Solubility of water in solvent at 20°C.	1.27% by wt.
Specific gravity at 20/20°C.	0.8162
Refractive index at 20°C.	1.4068
Specific heat at 25°C.	0.553 cal./g.
Surface tension at 25°C.	25.2 dynes/sq. cm.
Vapor pressure at 20°C.	5.2 mm. Hg
Viscosity at 20°C.	0.0074 poise
Weight per gallon at 20°C.	6.79 lbs.

DIISOBUTYL KETONE

Valerone $(C_4H_9)_2CO$

A water-white, stable liquid, miscible with most organic liquids, diisobutyl ketone has good solvency for cellulase acetate, nitrocellulose, vinyl resins, waxes, gums, natural and synthetic resins, and crude rubber. It is used principally as a high-boiler in nitrocellulose lacquers and vinyl resin coatings, where its slow evaporation rate is advantageous.

Table 12.26: Properties of Diisobutyl Ketone *(41)*

Typical Properties

Molecular Weight ($C_9H_{18}O$)	142.23	Boiling Range, 760 mm, °C	
Color (Pt-Co Scale), max	20	Initial Boiling Point, min	163
Evaporation Rate (n-butyl acetate = 1)	0.2	Dry Point, max	173
Weight/Vol, 20°C,		Freezing Point, °F (°C)	−43 (−42)
lb/gal (U.S.)	6.76	Flash Point, Tag Closed Cup, °F (°C)	120 (49)
kg/liter	0.81	Tag Open Cup, °F (°C)	131 (55)
lb/gal (Imperial)	8.11	Fire Point, °F (°C)	137 (58)
Solubility, 20°C, wt %		Flammable Limits in Air, % by volume	
In water	0.05	Lower, at 200°F (93°C)	0.81
Water in	0.75	Upper, at 200°F (93°C)	7.1
Dilution Ratio, toluene	1.5	Autoignition Temperature (ASTM D-2155), °F (°C)	745 (396)
VM & P naphtha	0.8	NFPA Classification 30	II
Refractive Index, 20°C	1.4230	DOT Classification	Combustible Liquid
Vapor Pressure, 20°C, mm Hg	1.7	DOT Labels Required	None
Specific Gravity, 20°/20°C	0.807-0.814		

(continued)

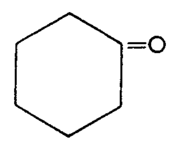
Table 12.26: (continued)

Solvent	Evap. Rate	Blush Res., % R. H. @ 80°F (27°C)	Solution Viscosity, 25°C, cp		
			RS. ½-Sec Cellulose Nitrate, 10 Wt/%	*FPC* 470 Resin[a], 20 Wt %	*Elvacite* 2010 Resin[b], 20 Wt %
Methyl Isoamyl Ketone	0.5	89	50	34	68
Methyl Amyl Acetate	0.5	92	128	Insol	Insol
Isobutyl Isobutyrate	0.4	92	128	Insol	Insol
Diisobutyl Ketone	0.2	95	160	75	Insol

[a]*product of Firestone Plastics Company* [b]*product of E. I. du Pont de Nemours Co., Inc.*

CYCLOHEXANONE

"Sextone", "Anon", Pimelin Ketone, Keto Hexamethylene



Cyclohexanone is a colorless to pale yellow, stable liquid with an odor suggestive of peppermint. It is made by the dehydrogenation of cyclohexanol. It is miscible in all proportions with most solvents, especially the common lacquer solvents and diluents, hydrogenated and chlorinated hydrocarbons, phenols, pyridine, and turpentine. It is a good solvent for cellulose ethers, esters, basic dyes, latex, fats, blown oils, waxes, crude rubber, and such gums and resins as ester gum, alkyds, vinyls, coumarone, 100% and modified phenol resins, cyclohexanone resins and many natural resins. It forms constant-boiling mixtures with camphor, tetrachloroethane, and trichloropropane. It has a very high dilution ratio as compared with the coal-tar hydrocarbons, a fact which accounts for its excellence as a solvent, especially in the lacquer industry.

Its low rate of evaporation and strong solvent powers impart blush resistance, good flow and working qualities to lacquers and give films that are clear, smooth and glossy and show good adhesion. It is also used in spraying and brushing lacquers and as a medium boiler. It is particularly effective for blending nitrocellulose with spirit-soluble and hydrocarbon-soluble resins and oils. Its solvency for basic dyes makes it applicable in wood stains. Other uses are in the air-drying and stoving type of synthetic resins, in plastics and molding powders, in paint and varnish removers, in spot and stain removers, in metal-degreasing preparations, in polishes, printing inks, as a leveling agent in dyeing, in delustering cellulose acetate, insecticides and pharmaceuticals.

Table 12.27: Properties of Cyclohexanone *(2)*

Boiling point	155.6°C.
Color	Water-white to pale yellow
Dielectric constant at 25°C.	18.2
Evaporation rate, approximate (toluene = 100)	20
Flash point (open cup)	130°F.
Freezing point	-45°C.
Solubility in water at 20°C.	8.7%
Specific gravity at 20°C.	0.944 - 0.950
Specific heat 15° to 18°C.	0.433 cal./g.
Refractive index	1.443 - 1.451
Viscosity (SUV at 100°F.)	33
Weight per gallon at 20°C.	7.9 lbs.
Acidity	Neutral
Distillation range	95% within 151° - 157°C.
Purity	98 - 100%
Residue	0.02%
Water content	0.2% max.

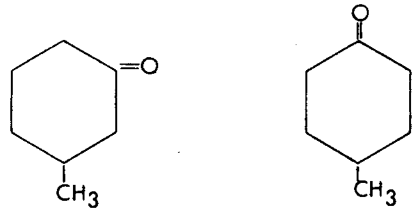
Table 12.28: Resin Solubility in Cyclohexanone (19)

Resin	Manufacturer	Viscosity at 25°C., cps. (1)	Toluene Dilution (2)	Heptane Dilution (2)
Acrylic				
"Acryloid" B-82	Rohm & Haas	32	>50	2
"Elvacite" 2010	DuPont	54	>50	7
Cellulosics				
Cellulose Acetate AB-141-95 (14% acetyl)	Eastman	9200	28	6.5
Cellulose Acetate Butyrate EAB-171-2 (17% butyryl)	Eastman	892	34	9.5
Cellulose Acetate Butyrate EAB-381-20 (37% butyryl)	Eastman	5060	>50	14
Ethyl Cellulose (N-22, 24 sec.)	Hercules	1408	>50	23
Half Second Butyrate AB-H	Eastman	242	>50	17
"Hercose" "C" Type A	Hercules	806	38	8.5
Nitrocellulose (RS 1/2 sec.)	Hercules	218	>50	10.5
Styrene				
Polystyrene	--	96	>50	24
SMA 4000A	Sinclair	19	>50	14.5
Vinyl				
BAKELITE Vinyl Resin AYAF	UCC	74	>50	7
BAKELITE Vinyl Resin VYHH	UCC	68	>50	14.5
BAKELITE Vinyl Resin XYHL	UCC	(3)	-	-
"Saran" F-120 (1000 cps.)	Dow	484	21	6.5
Epoxy				
BAKELITE Epoxy Resin EKR 2002	UCC	21	>50	9.5
Urethane				
"Estane" 5701F1	Goodrich	282	14	4.5
"Estane" 5707F1	Goodrich	388	6	2
Rosin-Ester				
"Amberol" 801 LT	Rohm & Haas	14	>50	19
"Cellolyn" 104	Hercules	20	>50	<1
Melamine-Formaldehyde				
"Cymel" 300	Am. Cyanamid	16	>50	>50
Alkyd				
"Beckasol" # 7	Reichhold	28	>50	47
"Beckasol" #31	Reichhold	25	>50	>50
Rubber				
"Parlon" S-20 (18 cps.)	Hercules	46	>50	22
"Pliolite" S-5	Goodyear	56	>50	30
Phenolic				
BAKELITE Phenolic Resin BKR 2620	UCC	23	16	5.5
Phenoxy				
BAKELITE Phenoxy Resin PKHH	UCC	Insoluble	-	-

(1) 10 grams resin, 90 grams cyclohexanone
(2) 10 grams of 10% resin solution, titrated with diluent (in ml.)
(3) Partially soluble

METHYL CYCLOHEXANONE

Methyl "Anon", "Sextone" B



Meta Para

Methyl cyclohexanone is a water-white to pale yellow liquid with an acetone-like odor. It is a mixture of two isomeric cyclic ketones made by the dehydrogenation of methyl cyclohexanol. It closely resembles cyclohexanone in its physical properties, miscibility, tolerance for non-solvents and solvent action. It differs from cyclohexanone in its somewhat slower evaporation rate and lower dilution ratios with aromatic hydrocarbons. Methyl cyclohexanone is especially suitable for phenolic and alkyd resins, crude rubber, nitrocellulose, ester gum and kauri. It is also an excellent agent for blending pyroxylin with resins, oils and rubber in lacquers. It is used in crystalizing lacquers, where its low evaporation rate retards evaporation sufficiently to permit crystal growth. It is also used in slow-setting varnish removers and in rubber cements.

Table 12.29: Properties of Methyl Cyclohexanone *(2)*

Boiling point	169.0° - 170.5°C.
Evaporation rate (approximate) (toluene = 100)	20
Flash point	53°C.
Freezing point	-70°C.
Refractive index at 25°C.	1.442 - 1.446
Solubility in water at 20°C.	2 - 3%
Specific gravity at 25/4°C.	0.910 - 0.914
Viscosity (SUV at 100°F.)	33
Weight per gallon	7.6 lbs.
Distillation range	165.0° - 172°C. 95% distills within 3.0°
Purity	98 - 100%
Residue	None
Water content	0.2%, max.

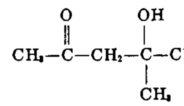
METHYL ACETONE

Methyl Ketone

Methyl acetone is a clear, colorless, flammable, volatile liquid, obtained from the product of the destructive distillation of wood. Although it varies in composition it is generally composed of acetone 35 to 60%, methanol 20 to 40%, and methyl acetate 20 to 30%.

DIACETONE ALCOHOL

Diacetone
4-Hydroxy-4-Methylpentanone-2
"Pyranton A"
Diacetonyl Alcohol



Diacetone alcohol is a flammable liquid that is colorless when pure, becoming yellow on aging; it has a mint-like odor. Made by the condensation of acetone, the commercial product contains up to 15% of acetone. For this reason the technical product is superior in its solvent power to the acetone-free grade. It is miscible with most organic liquids, as well as with water. It is a good solvent for cellulose acetate, nitrocellulose, cellulose acetobutyrate, cellulose acetopropionate, hydrocarbons, oils, fats, resins, gums and dyes. It has only limited solvency for dammar gum, polyvinyl acetate and the petroleum resins. A high-boiling solvent, diacetone alcohol also exhibits the desirable properties of reducing the viscosities of organic solutions of high solids content, and of minimizing temperature effects on viscosities. In most respects it is quite similar to acetone with the exception of a very much slower rate of evaporation

It is used in cellulose ester lacquers, particularly of the brushing type, where it produces brilliant gloss and hard film and where its lack of odor is desirable. It is used in lacquer thinners, dopes, wood stains, wood preservatives and printing pastes; in coating compositions for paper and textiles; in making artificial silk and leather; in imitation gold leaf; in celluloid cements; as a preservative for animal tissue; in metal-cleaning compounds; in the manufacture of photographic film; and in hydraulic brake fluids, where it is usually mixed with an equal volume of castor oil

Diacetone alcohol is available in two grades: technical, containing up to 15% acetone, and acetone-free.

Table 12.30: Physical Properties of Acetone-Free Diacetone Alcohol *(2)*

Boiling point at 760 mm.	167.9°C.
Coefficient of expansion (Cubical)	0.000533 per °F.
Color	Water-white to light straw
Flash point (open cup)	144°F.
Heat of combustion	8,601 cal./g.
Melting point	-47°C.
Specific gravity at 20/20°C.	0.937 - 0.946
Refractive index at 20°C.	1.4235
Viscosity (Saybolt)	
113 seconds at	-12°C.
674 seconds at	-30°C.
1,980 seconds at	-48°C.
Weight per gallon at 20°C.	7.83 lbs.
Acidity (as acetic)	0.05%
Distillation range at 760 mm.	
Below 135°C.	None
Below 158°C.	Not more than 5%
Above 170°C.	None
Nonvolatile matter	0.005% by wt. (max.)

ACETONYL ACETONE

Hexanedione-2,5 $(CH_3 \cdot CO \cdot CH_2)_2$

Acetonyl acetone, a diketone, is a water-white liquid with an agreeable odor. It is completely soluble in water, almost entirely soluble in such substances as toluene, kauri gum and rosin, and only partly soluble in raw linseed oil, shellac, dewaxed dammar and ester gum. It has been suggested as an intermediate in the manufacture of rubber accelerators, dyes, inhibitors, insecticides, and pharmaceuticals and for the preparatic of derivatives of thiophene, furan and pyrrole. It may also be employed in tanning hides and skins.

Table 12.31: Properties of Acetonyl Acetone *(2)*

Boiling point	191.4°C.
Dilution ratio (xylene)	1.8
Flash point	158°F.
Specific gravity at 20/20°C.	0.9710-0.9760
Solubility in water at 20°C.	Complete
Vapor pressure at 20°C.	0.5 mm. Hg
Weight per gallon at 20°C.	8.10 lbs.
Acidity (as acetic)	0.020% by wt., max.
Boiling range at 760 mm.	185° to 195°C.
Purity	98.0% by wt., min.
Water	Miscible with 19 vol. 60° Bé gasoline at 20°C.

MESITYL OXIDE

4-Methyl-3-Pentenone-2
Isopropylidone Acetone
Methyl Isobutenyl Ketone

$(CH_3)_2C{=}CH{\cdot}CO{\cdot}CH_3$

Mesityl oxide is an unsaturated, medium-boiling ketone made by the dehydration of diacetone alcohol. It is a colorless to straw-yellow, oily liquid with a peppermint-like odor. It will darken and form a solid residue on exposure and aging. It is miscible with most organic liquids and it is a good solvent for such substances as nitrocellulose, ethylcellulose, low-viscosity cellulose acetate, polyvinyl chloride, vinyl resins, hydrocarbons, raw linseed oil, kauri gum, rosin, ester gum and synthetic rubber. It will only partly dissolve shellac and dewaxed dammar.

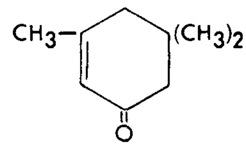
Mesityl oxide is used in lacquers and thinners where its presence in the solution lowers the viscosity and gives it both a high tolerance for hydrocarbons and resistance to humidity. Its excellent solvent power for gums and resins is especially applicable in vinyl-type resins, where it produces films that are tough, glossy and have good flow; its presence permits use of larger proportions of aromatic hydrocarbon diluents.

Table 12.32: Properties of Mesityl Oxide *(2)*

Boiling point at 760 mm.	129.5°C.
Coefficient of expansion	0.000599 per °F.
Color	Straw-yellow
Dielectric constant at 20°C.	15.4
Flash point (Tag closed cup)	83°F.
Heat of combustion	846.7 Cal. per mol
Heat of vaporization	85.9 cal./g.
Melting point	-59°C.
Solubility in water at 25°C.	3.4% by vol.
Solubility of water in solvent at 20°C.	3.4% by wt.
Specific gravity at 20/20°C.	0.853-0.856
Specific heat (21-121°C.)	0.521 cal./g.
Refractive index at 20°C.	1.4456
Vapor pressure at 20°C.	8.0 mm. Hg
30°C.	14.3 mm. Hg
40°C.	24.5 mm. Hg
Viscosity at 25°C.	8.79 millipoises
Weight per gallon at 20°C.	7.12 lbs.
Acidity (as acetic)	0.05%, max.
Distillation range (ASTM)	Below 120°C. None Above 135°C. None More than 95% distills over below 131°C.
Purity	95% by wt., min.
Water	Miscible without turbidity with 19 vols. of 60° Bé gasoline at 20°C. (approx. 0.20% by wt.)

ISOPHORONE

3,5,5-Trimethylcyclohexene-2-one-1



Isophorone is a stable, colorless, volatile liquid with a mild odor. It is only slightly soluble in water, but miscible with most lacquer solvents. It is an excellent solvent for many types of cellulose esters, cellulose ethers, oils, fats, gums and resins, both natural and synthetic. It is the most powerful solvent for nitrocellulose and "Vinylite" resins. Isophorone has one of the highest aromatic hydrocarbon dilution ratios for nitrocellulose—5.7 for toluene and 5.1 for xylene. It will dissolve 30% of "Vinylite" resin without gelling. At ordinary temperatures solutions can be made of 1/2 second RS nitrocellulose containing 45% solids. Isophorone is used in the manufacture of coatings, inks, stencil pastes and as a thinner in synthetic resin finishes.

Table 12.33: Properties of Isophorone *(2)*

Boiling point at 760 mm.	215.2°C.
Dilution ratios	
Toluene	5.7
Xylene	5.1
"Troluoil"	1.0
Mineral spirits	0.7
Flash point (open cup)	205°F.
Freezing point	-8.1°C.
Solubility in water at 20°C.	1.2% by wt.
Solubility of water in solvent at 20°C.	3.8% by wt.
Specific gravity at 20/20°C.	0.9200-0.9250
Vapor pressure at 20°C.	0.25 mm. Hg
Weight per gallon at 20°C.	7.68 lbs.
Acidity (as acetic)	0.02% by wt., max.
Distillation range at 760 mm.	205°-220°C.
Color	Not darker than 0.05 g. $K_2Cr_2O_7$ per l. of water
Purity	98.0% by wt., min.
Water content	Miscible with 19 vol. 60° Bé gasoline at 20°C.

FENCHONE

Fenchone is a liquid ketone closely resembling camphor.

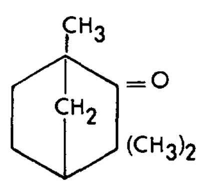


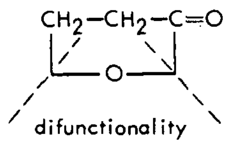
Table 12.34: Properties of Fenchone *(2)*

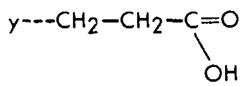
Boiling point	191.0°C.
Dilution ratio:	
with coal-tar naphtha	1.3 final conc. 8.0
with hi-flash naphtha	1.2 final conc. 8.2
Kauri-butanol	All proportions in 50% sol. with mineral spirits 131
Optical activity	+7.4
Refractive index at 20°C.	1.4625
Specific gravity at 15.5°C.	0.9457
Aniline point (—)	54°C.

Distillation Range (Calculated from 50:50 Min. Spirits)	
5%	193.0°C.
10%	193.4°C.
20%	193.8°C.
40%	194.2°C.
60%	194.5°C.
80%	195.4°C.
90%	196.0°C.
95%	197.5°C.

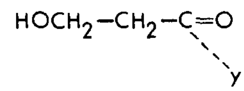
BETA-PROPIOLACTONE

BPL





Beta-Propionic Acid Derivatives



Hydracrylic Acid Derivatives

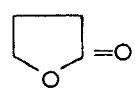
Table 12.35: Physical Properties of Beta-Propiolactone *(42)*

Physical state	Liquid
Color	Colorless
Odor	Pungent, acrylic
Boiling point at 10 mm Hg, deg C	51
100 mm Hg	100.0
400 mm Hg	139.7
760 mm Hg	162.3
Melting point, deg C	—33.4
Refractive index n_D^{20}	1.4131
Specific gravity, 20/20 C	1.1490
Pounds per gallon at 20 C	9.56
Flash point, Tag open cup, deg F	165

Solubility: BPL is miscible at room temperature with most organic solvents such as ether, alcohol (reacts), benzene, acetone, and acetic acid. Solubility in water at 25 C is 37 per cent by volume, with moderately fast hydrolysis to hydroxypropionic (hydracrylic) acid.

GAMMA-BUTYROLACTONE

BLO



Gamma-butyrolactone is a powerful solvent and undergoes many reactions that make it of considerable interest in synthesis. It is a colorless hygroscopic liquid over a wide temperature range. It is soluble in acetone, benzene, carbon tetrachloride, ethyl ether, methanol, monochlorobenzene and water in all proportions.

Table 12.36: Properties of Gamma-Butyrolactone *(49)*

Appearance	clear liquid
Color (APHA)	40
Purity	99.5% min.
Moisture	0.1% max.
Free acid, as hydroxybutyric	0.1% max.
Molecular weight	86
Boiling point	204°C
Freezing point	—44°C
Viscosity (25°C)	1.7 cp
Specify gravity (d_4^{25})	1.124
Flash point, tag closed cup	93°C (200°F)
Fire point	99°C (210°F)
pH (10% aqueous solution)	4.5
Refractive index (n_D^{25})	1.435
Heat of vaporization, Clausius-Clapeyron (calc)	133 cal/g
Heat of solution	598 cal/mol
Heat of combustion	492 kcal/mol
Specific heat (25°C)	0.40 cal/g/°C
(60°C)	0.45 cal/g/°C
Dielectric constant (20°C)	39
Critical pressure	500 psi (35 kg/cm²)
Critical temperature	436°C

Solubility: soluble in acetone, benzene, carbon tetrachloride, ethyl ether, methanol, chlorobenzene, and water in all proportions.

(continued)

Table 12.36: (continued)

Vapor Pressure of Butyrolactone

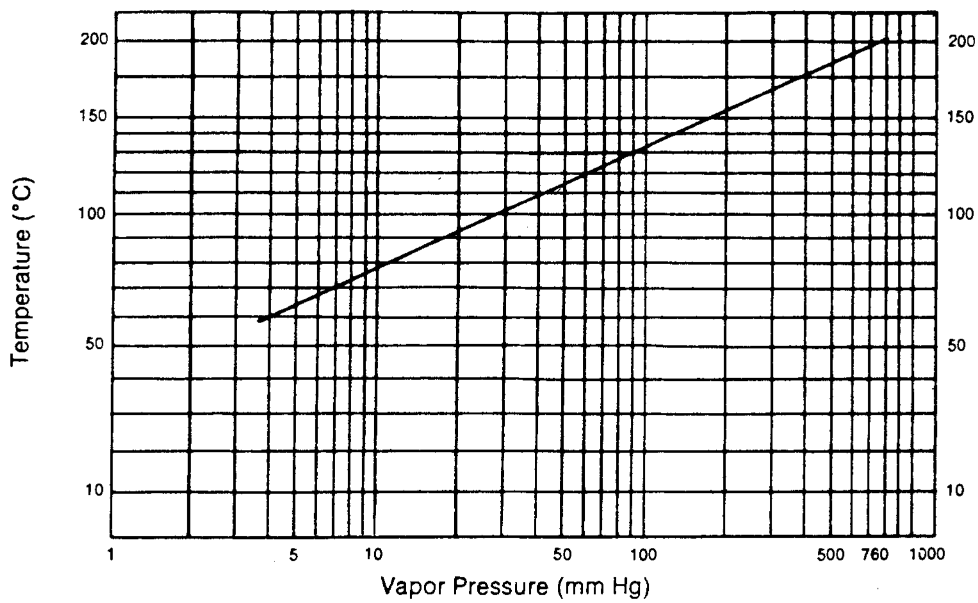


Table I. Percentage of Butyrolactone Hydrolyzed under Acid Conditions as Function of Time, Temperature, and Concentration

Concentration (%)		Time (hours)							
		1		3		5		24	
BLO	Dilute HCl	Room Temperature	65°C	Room Temperature	65°C	Room Temperature	65°C	Room Temperature	65°C
99	1	—	—	—	0.34	—	0.54	—	0.56
98	2	—	0.32	0.24	0.97	0.42	1.18	0.97	1.21
95	5	—	0.73	0.49	2.35	0.68	2.53	1.94	3.11
90	10	—	1.23	0.59	4.43	0.99	4.87	3.14	5.95
80	20	0.28	2.17	1.02	8.15	1.62	9.15	5.52	10.95
50	50	0.92	6.48	2.57	15.98	4.07	17.92	12.10	18.41

BUTYROLACTONE refers to gamma butyrolactone

Table II. Percentage of Butyrolactone Hydrolyzed at pH 7 as Function of Time and Concentration*

Concentration (%)†		Time (hours)		
BLO	H_2O	8	24	48
80	20	—	0.33	1.7
50	50	1.7	11.1	17.4

*Tests were conducted at 65°C. No observable hydrolysis was detected at room temperature.
†At concentrations of up to 10 per cent water, no hydrolysis was observed in 46 hours.

(continued)

Table 12.36: (continued)

Table III. Bunsen Coefficients of Butyrolactone (cc gas/cc solvent converted to STP)

Gas	25°C	45°C	75°C
Hydrogen	0.12	0	0
Carbon Monoxide	0.09	0.044	0
Carbon Dioxide	3.6	2.7	1.1
Methyl Acetylene	37.8	12.5	10.8
Acetylene	11.8	8	1.45
Vinyl Acetylene	145.1 (27°C)	33.1	23.1 (73°C)

Table IV. Solubilities of Compounds in Butyrolactone

Compound	% Soluble
Acrylonitrile, (high) spec. vis. 8.5[a]	>10[b]
Acrylonitrile, (low) spec. vis. 3.18[a]	>16[b]
Acrylonitrile, (low) spec. vis. 2.45[a]	20[b]
Acrylonitrile, (low) spec. vis. 2.11[a]	20[b]
"Amberol" Resin 820 (Rohm & Haas)	50
"Aroclor" (60% Cl), chlorinated biphenyl (Monsanto)	50
Cellulose Acetate	5[c]
Cellulose Acetate Butyrate	10
Cellulose Acetate Propionate	10
Cellulose Nitrate	25
"Clorafin" (70% Cl), chlorinated paraffin (Hercules Powder)	50
DDT	50
"Epon" 1007, epoxy resin (Shell Chemical)	25
"Epon" 1009, epoxy resin (Shell Chemical)	25
Ester Gum	50[c]
Ethyl Cellulose	25[c]
"Formvar," polyvinyl formal resin (Monsanto)	> 5
"Geon" Polyblend, polyvinyl chloride (Goodrich)	>10[c]
"Geon" 102, polyvinyl chloride (Goodrich)	> 5[c]
"Geon" 202, polyvinyl chloride (Goodrich)	>10[c]
HET Anhydride	60[c]
Methyl Methacrylate Polymer	25
Methyl Vinyl Ether Polymer	50
"Neolyn" 23 Resin (Hercules Powder)	50
"Parlon," chlorinated rubber (Hercules Powder)	>25
Polyvinyl Butyral	25[c]
Pyromellitic Acid	20
"Saran" F-120, vinylidene chloride (Dow Chemical)	>10
Shellac	25
Polystyrene	>25
Vinyl Acetate Polymer	>25
1-Vinyl-2-Pyrrolidone Polymer	>25
9-Vinylcarbazole, Monomer and Polymer	>25
"Vinylite" VYNW, vinyl chloride resin (Union Carbide)	> 5[c]
"Vinylite," XYSG, vinyl resin (Union Carbide)	10[c]

[a] 1 gram polymer dissolved in 100 ml BLO.

[b] Heated for 1 hour at 100°C. and then cooled to room temperature.

[c] Solubility after 1 hour at 100°C.

BUTYROLACTONE refers to gamma butyrolactone

COMPARATIVE DATA

Table 12.37: Ashland Ketones *(69)*

PRODUCT	LB./GAL. 20° C	SP. GR. 20°/20° C	BOILING RANGE °C	°F	FL. PT. °F TCC	EVAP. RATE[1]
Acetone	6.59	0.790	55-56	131-133	−4	14.4
Methyl Ethyl Ketone	6.71	0.806	78-81	172-178	24	5.7
Methyl Propyl Ketone	6.72	0.807	101-105	214-221	46	2.3
Methyl Isobutyl Ketone	6.67	0.802	114-117	237-243	60	1.6
Methyl Isoamyl Ketone	6.78	0.813	141-148	286-298	98	0.47
Diacetone Alcohol, A.F.	7.82	0.939	145-172	293-342	126	0.12
Methyl Amyl Ketone	6.80	0.818	147-154	297-309	102	0.40
Cyclohexanone	7.88	0.946	156-158	313-316	111	0.20
Diisobutyl Ketone	6.75	0.809	163-173	325-343	120	0.20
Isophorone	7.68	0.922	210-218	410-424	179	<0.05

[1] n-Butyl Acetate = 1

Table 12.38: Chemcentral Ketones and Miscellaneous Active Solvents *(67)*

KETONES & MISC. ACTIVE SOLVENTS	CAS	Mole Weight	% Purity Comm. Prod.	Spec. Grav. @ 20/20°C	Lbs./Gal. @ 20°C	Coeff. of Expan. Per °C	ΔSp. Gr. Per °C	Refractive Index @ 20°C	Distillation Range @ 760 mm Hg		Vapor Press. @ 20°C mm Hg
									°C	°F	
ACETONE	67-64-1	58 08	99 5	0 792	6.59	0.00151	00102	1.3584	55.5-56.5	132-134	185.0
CYCLOHEXANONE	108-94-1	98 14	99.8	0 948	7 89	0.00091	.00064	1.4507	154-157	309-315	7.0(30°)
DIACETONE ALCOHOL, A.F.	123-42-2	116 16	99	0 939	7.82	0.00100	.00072	1.4234	145-172	295-342	1.0
DIISOBUTYL KETONE (DIBK)	108-83-8	142 23	95	0.808	6.72	0.00105	00066	1.4230	163-173	325-343	1.4
DIMETHYL FORMAMIDE (DMF)	**68-12-2**	**73.09**		**0.951**	**7.92**	**0.00100**	**.00072**	**1.4269**	**(95%) 2° incl. 153°**	**(95%) 3.6° incl. 307.4°**	**2.6**
FURFURAL	98-01-1	96.08	98	1 160	9.68		.00110	1.5261	161.7-BP	323.1-BP	1.7
ISOPHORONE	78-59-1	138.20	98	0 923	7.68	0.00087	.00058	1.4775	215-220	418-428	0.2
METHYL AMYL KETONE (MAK)	110-43-0	114.19		0.817	6.80				149-151	300-304	
METHYL ETHYL KETONE (MEK)	78-93-3	72 10	99 9	0.806	6.71	0.00128	.00084	1.3787	79-80	174-176	85.0
METHYL ISOAMYL KETONE (MIAK)	**110-12-3**	**114.2**	**97.5**	**0.813**	**6.76**	**0.00091**			**141-148**	**287-297**	
METHYL ISOBUTYL KETONE (MIBK)	108-10-1	100 16	99.8	0.802	6.67	0.00120	.00078	1.3958	114-117	237-243	16.0
METHYL n-PROPYL KETONE (MPK)	107-87-9	86.13	99	0.808	6.73	0.00125	.00082	1.3895	97-107	206-225	26.9
TETRA HYDRO FURAN (THF)	109-99-9	72.10		0.888	7.40			1.4073	65-67	149-153	45.0
2-NITROPROPANE (NiPar** S-20)	79-46-9	89.09	94	0.992	8.24	0.00104		1.3941	119-122	246-252	12.9

KETONES & MISC. ACTIVE SOLVENTS	Evap. Rate vs. B. Acet. = 1	Solubility % by Wt. @ 20°C		Dilution Ratio		Bl. Res. % Rel. Hum. @ 80°F	V. 8% NC @ 25°C CPS	Freeze Point °C	Flash Point T.C.C. °F	Explosive Limits % by Vol. in Air		Solubility Parameter
		In H_2O	Of H_2O	Toluol	Lactol					Lower	Upper	
ACETONE	7.7	∞	∞	4.6	0.7	< 20	12	−95	−4	2.6	12.8	10.0
CYCLOHEXANONE	0.31	2.3	8.0	6.1	1.2	92	76	−47	129	1.1	8.6	9.7
DIACETONE ALCOHOL, A.F.	0.14	∞	∞	3.0	0.5	76	130	−42.8	126	1.8	6.9	9.2
DIISOBUTYL KETONE (DIBK)	0.2	0.05	0.75	1.5	0.8	95	68	−41.5	120	0.8	6.2	7.8
DIMETHYL FORMAMIDE (DMF)	**0.17**	**∞**	**∞**					**−61**	**136**	**2.2**	**15.2**	**1.21**
FURFURAL		8.3	4.8					−36.5	152[a]	2.1	19.3	
ISOPHORONE	0.03	1.2	4.3	6.2	1.2	96	117	−8.1	179	0.8	3.8	9.1
METHYL AMYL KETONE (MAK)	0.4	0.46	1.31	3.9	1.2	93	26		102			9.0
METHYL ETHYL KETONE (MEK)	4.6	27.0	12 5	4.3	0.9	45	14	−86.9	23	1.8	10.0	9.3
METHYL ISOAMYL KETONE (MIAK)	**0.5**	**0.5**	**1.2**	**4.1**	**1.2**	**89**	**27**		**96**			**8.3**
METHYL ISOBUTYL KETONE (MIBK)	1.6	2.0	1.0	3.5	1.0	78	23	−80.3	60	1.2		8.4
METHYL n-PROPYL KETONE (MPK)	2.5	4.3	3.3	3.9	1.0	70	16	−77.5	45	1.4	7.5	8.9
TETRA HYDRO FURAN (THF)	6.3	∞	∞	2.8	1.0	50	22		4	2.0	11.8	9.9
2-NITROPROPANE (NiPar** S 20)	1.10	1.7	0.6	1.2	0.4	82	64	−163	82	2.6		9.1

**Trademark Angus

[a] Tag Open Cup Flash Point

[b] @ 25°C

Table 12.39: Eastman Chemical Ketones *(41)*

	Evaporation Rate n-BuOAc = 1	Lb/ Gal @ 20°C	Color Pt-Co Max	Specific Gravity @ 20°/20°C	Acidity, as Acetic Acid Max Wt %	Boiling Range °C	Freezing Point °C	Flash Point TCC °C (°F)	Assay Min Wt %
Acetone CH_3COCH_3	5.7	6.59	5	0.792	0.004	55-57	-95	-20 (-4)	99.5
Methyl n-Propyl Ketone (MPK)[a] $CH_3COC_3H_7$	2.3	6.74	15	0.810	0.02	101-105	-86	8 (46)	90.0
Methyl Isobutyl Ketone (MIBK)[a] $CH_3COCH_2CH(CH_3)_2$	1.6	6.67	10	0.802	0.01	114-117	-84	16 (60)	99.0
Methyl Isoamyl Ketone (MIAK)[a] $CH_3COC_2H_4CH(CH_3)_2$	0.5	6.76	10	0.813	0.02	141-148	-74	36 (96)	98.0
Methyl n-Amyl Ketone (MAK)[a,b] $CH_3COC_5H_{11}$	0.4	6.80	10	0.818	0.02	147-154	-33	39 (102)	98.0
Diisobutyl Ketone (DIBK) $(CH_3)_2CHCH_2COCH_2CH(CH_3)_2$	0.2	6.76	20	0.811	0.02	163-176	-42	49 (120)	—
EASTMAN® C-11 Ketone	0.02	7.02	75	0.84	0.10	175-250	-8	84 (184) (seta-flash)	—

[a]*Urethane grade*
[b]*Kosher certified*

Table 12.40: Exxon Ketones *(8)*

	Methyl Ethyl Ketone	Methyl Isobutyl Ketone
Distillation Range, °C	79–81	114–117
Specific Gravity, 20°/20°C	0.81	0.80
Viscosity @ 25°C, cp	0.4	0.6
Vapor Pressure @ 20°C, mmHg	80	15
Density @ 20°C, lb/gal	6.71	6.68
Flash Point, TCC °C*	21	62
Acidity, wt % MAX**	0.003	0.01
Evaporation Rate, n-BuAc=100	572	165
Purity, wt % (MIN)	)99.5	)99.0
Hildebrand Solubility Parameter	9.3	8.6
Surface Tension @ 20°C, dynes/cm	25	24
Water Content, wt % (MAX)	0.1	0.1
Water Solubility @ 25°c, wt %		
In water	26.3	1.7
Water in	11.8	1.9
Inhalation TLV***	200	50
CAS Registry Number	78-93-3	108-10-1

*Tag Closed Cup, ASTM D 56 **As acetic acid ***Threshold Limit Value is a registered trademark of the ACGIH

Table 12.41: Hoechst-Celanese Ketones *(42)*

Physical Properties

Autoignition Temperature, °C	515.5	Heat of Combustion, kg-cal/g mole	582.3
Boiling Point at 760 mm Hg, °C	79.6	Heat of Fusion, cal/g mole	1.78
Boiling Point at 760 mm Hg, °F	175.3	Heat of Vaporization, btu/lb at 20°C	212.4
Coefficient of Thermal Expansion per °C at 20°C	1.126×10^{-3}	Molecular Weight	72.11
		Refractive Index, n_D^{20}	1.3787
Critcal Pressure, atmospheres	41.0	Solubility at 20°C at wt % in water	26.8
Critical Temperature, °C	252.5	water in	12.5
Dielectric Constant, 20°C	15.45	Specific Gravity, 20/20°C	0.8062
Evaporation Rate (BuAc = 1)	5.7	Specific Heat of Liquid, at 20°C, cal/g	.525
Flammable Limits		Surface Tension at 20°C, dynes/cm	24.6
(lower limit, vol %)	2.0	Vapor Density (air = 1)	2.5
(upper limit, vol %)	11.0		
Flash Point, Tag Open Cup, °F	30	Vapor Pressure, at 20°C, mm Hg	77.5
Tag Closed Cup, °F	20	Viscosity at 25°C, centipoise	0.40
Freezing Point, °C	-86.7	Weight, pounds per gallon at 20°C	6.71

Table 12.42: Shell Chemical Ketones *(14)*

Typical properties of the compounds

	Acetone	Methyl ethyl ketone	Methyl isobutyl ketone	Diacetone alcohol
Molecular weight	58.080	72.108	100.162	116.162
Specific gravity (apparent)				
60/60°F	0.7967	0.8105	0.8055	0.9441
20/20°C	0.7925	0.8065	0.8022	0.9409
25/25°C	0.7879	0.8023	0.7986	0.9374
Weight per U.S gallon (in air)				
60°F	6.636	6.750	6.709	7.863
20°C	6.595	6.711	6.676	7.830
25°C	6.549	6.668	6.638	7.792
Boiling point @ 760 mm				
°C	56.13	79.64	116.2	169.2
°F	133.03	175.26	241.16	336.6
Boiling point change				
°C/mm @ 760 mm	0.0385	0.04	0.046	0.075
Vapor pressure @ 20°C, mm	185.95	70.21	14.96	0.81
Freezing point @ 760 mm, °C	-94.897	-86.69	-83.5	-44.
Refractive index n_D^{20}	1.35900	1.37880	1.3957	1.4234
Heat of vaporization				
cal/g @ 760 mm	122.09	105.95	82.50	90.0
Heat of fusion at melting point				
cal/g	23.53	24.86		
Specific heat (liquid)				
cal/g °C @ 25°C	0.51	0.51	0.53	0.62
Flash point, tag open cup, °F approx.	15.	20.	79.	135.
tag closed cup, °F approx.	-15.	23.	60.	126.
Flammable limits in air				
% of compound, upper	11.0v	11.5v	7.5v	
lower	3.0v	1.81v	1.4v	
Solubility, % wt.				
in water, @ 20°C	complete	27.1	2.04	complete
water in, @ 20°C	complete	12.5	2.41	complete
Azeotrope with water,				
%w compound	none	88.73	75.7	12.7
Boil pt. @ 760 mm, °C		73.41	87.93	98.8
Viscosity, cps				
@ 20°C			0.583	
@ 25°C	0.3075	0.41	0.55	2.9
@ 30°C		0.365		
Surface tension				
dyne/cm 20°C	22.32	24.6	23.64	28.9

Table 12.43: Union Carbide Ketones *(19)*

Ketones	Formula	Molecular Weight	Relative Evaporation Rate nBuAc = 1	Vapor Pressure at 20°C, mm Hg	Density at 20°C, lb/gal	Gravity at 20/20°C	Specific Hoy Solubility Parameters: Total	Hydrogen Bonding	Polar	Non-Polar
Acetone	CH_3COCH_3	58.08	14.40	184.0	6.59	0.792	9.6	5.4	4.8	6.4
Cyclohexanone	$CH_2[CH_2]_4CO$	98.15	0.40	3.0	7.89	0.948	10.4	5.4	4.6	7.6
Diacetone Alcohol	$CH_3C(OH)(CH_3)CH_2COCH_3$	116.16	0.12	1.0	7.82	0.940	9.8	6.1	5.6	5.2
Diisobutyl Ketone	$[CH_3CH(CH_3)CH_2]_2CO$	142.24	0.15	1.0	6.77	0.808	8.1	1.9	3.3	7.1
Isophorone	$CH{=}C(CH_3)CH_2C(CH_3)_2CH_2CO$	138.21	0.02	0.1	7.68	0.923	9.4	1.6	4.6	8.0
Methyl n-Amyl Ketone	$CH_3COC_5H_{11}$	114.19	0.28	2.0	6.80	0.817	9.0	3.5	3.7	7.4
Methyl Ethyl Ketone	$CH_3COC_2H_5$	72.10	6.60	75.0	6.71	0.806	9.5	4.6	4.5	6.9
Methyl Isobutyl Ketone	$CH_3COCH_2CH(CH_3)_2$	100.16	1.60	15.0	6.67	0.802	8.6	2.9	3.9	7.1

Ketones	Viscosity at 20°C, cP	Surface Tension at 20°C, dynes/cm	Boiling Point at 760 mm Hg, °C	Solubility at 20°C, Percent by Wt: In Water	Water In	Flash Point, Tag Closed Cup, °F	Electrical Resistance[a], Megohms	Odor Detection Threshold[b] ED50, ppm	Title III Listed Hazardous Air Pollutant[c]	CAS Registration Number
Acetone	0.3	23.7	56.3	Complete		0			No	67-64-1
Cyclohexanone	2.2	35.0	155.7	2.3	8.0	111			No	108-94-1
Diacetone Alcohol	3.2	30.3	169.2			133			No	123-42-2
Diisobutyl Ketone	1.0	23.2	169.4	0.05	0.75	120	0.06		No	108-83-8
Isophorone	2.6	31.6	215.2	<0.02	4.3	190			Yes	78-59-1
Methyl n-Amyl Ketone	0.8	26.7	151.5	0.4	1.3	105	0.75	0.02	No	110-43-0
Methyl Ethyl Ketone	0.4	24.5	79.6	24.0	10.0	21			Yes	78-93-3
Methyl Isobutyl Ketone	0.6	24.0	116.1	2	1	61	0.45		Yes	108-10-1

(a) Measured with a Ransburg Model 219CB Paint Resistance Tester. Values listed are for commercially available materials.

(b) Odor Detection Threshold is the concentration of odorant in ppm necessary for 50% of a test panel to detect or perceive an odor in air.

(c) Hazardous Air Pollutants listed under Title III of the Clean Air Act.

(continued)

Table 12.43: (continued)

UCAR® Ketones Selection Guide

Type	Ketone	Relative Evaporation rate (BuAc = 100)	TYPE OF COATING: Nitrocellulose: Conventional	Nitrocellulose: Hot Spray	Nitrocellulose: High-Low	Nitrocellulose: Multi-Color	Nitrocellulose: Emulsions	Vinyl	Cellulose Acetate	1/2-s Butyrate	Ethyl Cellulose	Acrylic	Urethane	Water Soluble
Fast Evaporating	Acetone	1440	●		●			●	●	●	●	●		●
	Methyl Ethyl Ketone	631	●		●			●	●	●	●	●	●	●
Medium Evaporating	Methyl Isobutyl Ketone	162	●	●		●	●	●		●	●	●	●	●
	Methyl n-Amyl Ketone	40	●	●	●			●		●	●	●	●	
Slow Evaporating	Cyclohexanone	23	●	●	●			●	●	●	●	●		
	Diisobutyl Ketone	17	●	●	●	●	●			●				
	Diacetone Alcohol	12	●	●	●			●	●	●	●	●		●
	Isophorone	2		●	●	●	●	●	●		●	●		
	Isobutyl Heptyl Ketone	1					●	●						

General Solvent Properties of UCAR® Ketones

	Relative Evaporation Rate (BuAc = 100)	Weight per Gallon at 20°C, lb	8 Percent Solution of R.S. 1/2-s Nitrocellulose: Dilution Ratio: Toluene	Naphtha	Xylene	Blush Resistance at 80°F, % RH ± 2%	Viscosity at 25°C, cP	Solubility Parameters: Total	Polar	Hydrogen Bonding	Status under Rule 66-Type Regulations[a]
Acetone	1440	6.59	4.5	0.7	—	<35	9	9.62	4.79	5.39	NPCR
Methyl Ethyl Ketone	631	6.71	4.3	0.9	—	51	10	9.45	4.52	4.63	NPCR
Methyl Isobutyl Ketone	162	6.67	3.6	1.0	3.2	78	19	8.58	3.94	2.88	PCR-20%
Methyl n-Amyl Ketone	40	6.81	3.9	1.2	3.6	92	25	8.98	3.73	3.52	NPCR
Cyclohexanone	23	7.89	5.7	1.1	4.8	92	79	10.42	4.58	5.39	NPCR
Diisobutyl Ketone	17	6.72	1.5	0.6	1.5	95	65	8.06	3.32	1.88	PCR-20%
Diacetone Alcohol	12	7.82	3.0	0.5	2.3	76	148	9.78	5.56	6.14	PCR-20%
Isophorone	2	7.67	6.2	—	5.1	96	104	9.36	4.58	1.55	PCR-5%
Isobutyl Heptyl Ketone	1	6.84	Imm.	Imm.	Imm.	—	—	7.95	2.93	1.74	PCR-20%

Footnote:
(a) NPCR, Nonphotochemically Reactive; PCR-20% and PCR-5%, Photochemically Reactive — volume percent without requiring emission control.

(continued)

Table 12.43: (continued)

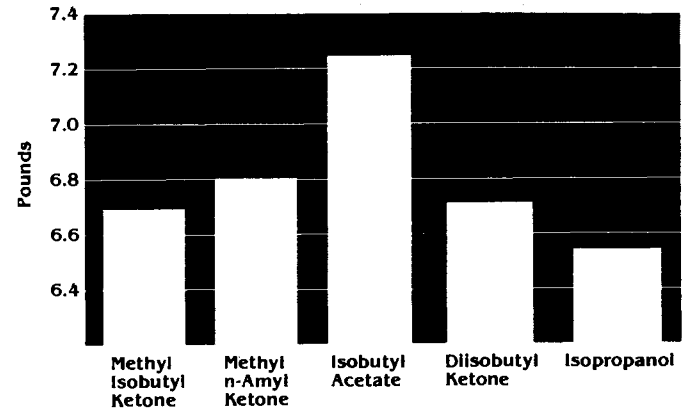
Resin Solubilities of UCAR® Ketones

Ketone	Cellulose Acetate, 41% Acetyl	Cellulose Acetate Butyrate, 17% Butyryl	Cellulose Acetate Butyrate, 37% Butyryl	Ethyl Cellulose, 47-49% Ethoxyl	Polystyrene	Poly-(methyl Methacrylate)	UCAR Solution Vinyl Resin VYHH	Polyvinyl Acetate AYAF
Acetone	S	S	S	S	PS	S	S	S
Cyclohexanone	S	S	S	S	S	S	S	S
Diacetone Alcohol	S	PS	S	S	I	S	S	S
Diisobutyl Ketone	I	I	I	SW	SW	I	S-G	PS
Isobutyl Heptyl Ketone	I	I	I	SW	I	I	I	I
Isophorone	S	S	S	S	S	PS	S	S
Methyl Ethyl Ketone	S	S	S	S	S	S	S	S
Methyl Isobutyl Ketone	I	I	S	S	S	S	S	S
Methyl n-Amyl Ketone	I	I	S	S	S	S	S	S

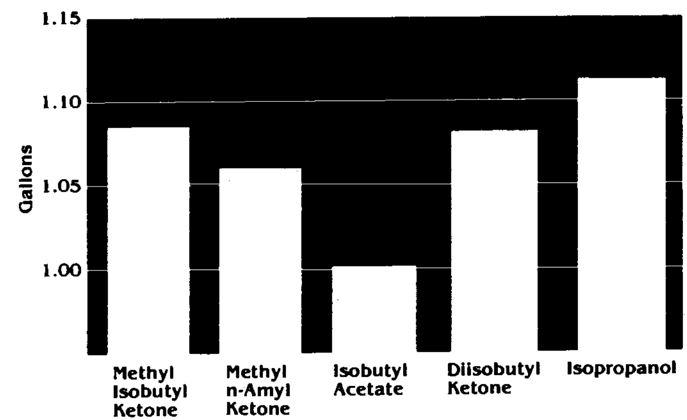
NOTE:

Concentration = 0.5 g resin to 4.5 ml of solvent
S = Soluble
I = Insoluble
SW = Swelling
PS = Partly soluble
S-G = Soluble, tendency to gel

Weight of One Gallon of Solvent



Volume of 7.24 Pounds of Solvent



(continued)

Table 12.43: (continued)

Constant Boiling Mixtures

Mixture	COMPONENTS: Specific Gravity at 20/20°C	COMPONENTS: Boiling Point at 760 mm Hg, °C	AZEOTROPE: Boiling Point at 760 mm Hg, °C	Composition at 20°C, % by Weight: In Azeotrope	Composition at 20°C, % by Weight: In Upper Layer	Composition at 20°C, % by Weight: In Lower Layer	Relative Volume of Layers at 20°C	Sp Gr at 20/20°C of Azeotrope or Layers
Acetone	0.7918	56.3	39.3	33.0				1.040
Carbon Disulfide	1.2657	46.2		67.0				
Acetone	0.7918	56.3	64.7	20.0				1.268
Chloroform	1.4925	61.2		80.0				
Acetone	0.7918	56.3	57.5[a]	30.0				[b]
Chloroform	1.4925	61.2		47.0				
Methanol	0.7922	64.7		23.0				
Acetone	0.7918	56.3	49.8	59.0				
Hexane	0.6717	68.7		41.0				
Acetone	0.7918	56.3	47.0	45.0				0.720
Hexane (Commercial)	0.6717	68.7		48.0				
Methyl Acetate	0.9355	57.0		7.0				
Acetone	0.7918	56.3	53.3	56.5				0.764
Isopropyl Ether	0.7250	68.3		43.5				
Acetone	0.7918	56.3	55.7	88.0				0.795
Methanol	0.7925	64.7		12.0				
Acetone	0.7918	108.7[c]	102[c]	68.0				0.796
Methanol	0.7925	109.1[c]		32.0				
Acetone	0.7918	132.1[d]	124[d]	54.0				0.796
Methanol	0.7925	128.4[d]		46.0				
Acetone	0.7918	151.4[e]	140[e]	44.0				0.796
Methanol	0.7925	143.8[e]		56.0				
Acetone	0.7918	56.3	53.7	5.8				0.898
Methanol	0.7925	64.7		17.4				
Methyl Acetate	0.9355	57.0		76.8				
Acetone	0.7918	56.3	55.6	48.0				0.854
Methyl Acetate	0.9355	57.0		52.0				
Acetone	0.7918	83.8[f]	81.4[f]	98.7				0.795
Water	1.0000	127.3[f]		1.3				
Cyclohexanone	0.9482	155.7	95	38.4	92.0	2.3	U 41.5	U 0.953
Water	1.0000	100.0		61.6	8.0	97.7	L 58.5	L 1.000
Diacetone Alcohol	0.9395	169.2	99.6	13.0				1.002
Water	1.0000	100.0		87.0				
Diisobutyl Ketone	0.8075	169.4	97.0	48.1	99.25	0.05	U 53.4	U 0.810
Water	1.0000	100.0		51.9	0.75	99.95	L 46.6	L 1.000
Isobutyl Heptyl Ketone	0.8215	218.2	99.0	16.0	99.8	0.01	U 19.0	U 0.810
Water	1.0000	100.0		84.0	0.2	99.99	L 81.0	L 1.000
Isophorone	0.9220	215.3	99.5	16.1	95.7	1.2	U 16.0	U 0.929
Water	1.0000	100.0		83.9	4.3	98.8	L 84.0	L 0.999

Footnotes:

a) Distillation barrier present
b) Homogeneous at 20°C
c) at 4.56 atm
d) at 7.82 atm
e) at 11.6 atm
f) at 20 psig
g) at 30/20°C

(continued)

Table 12.43: (continued)

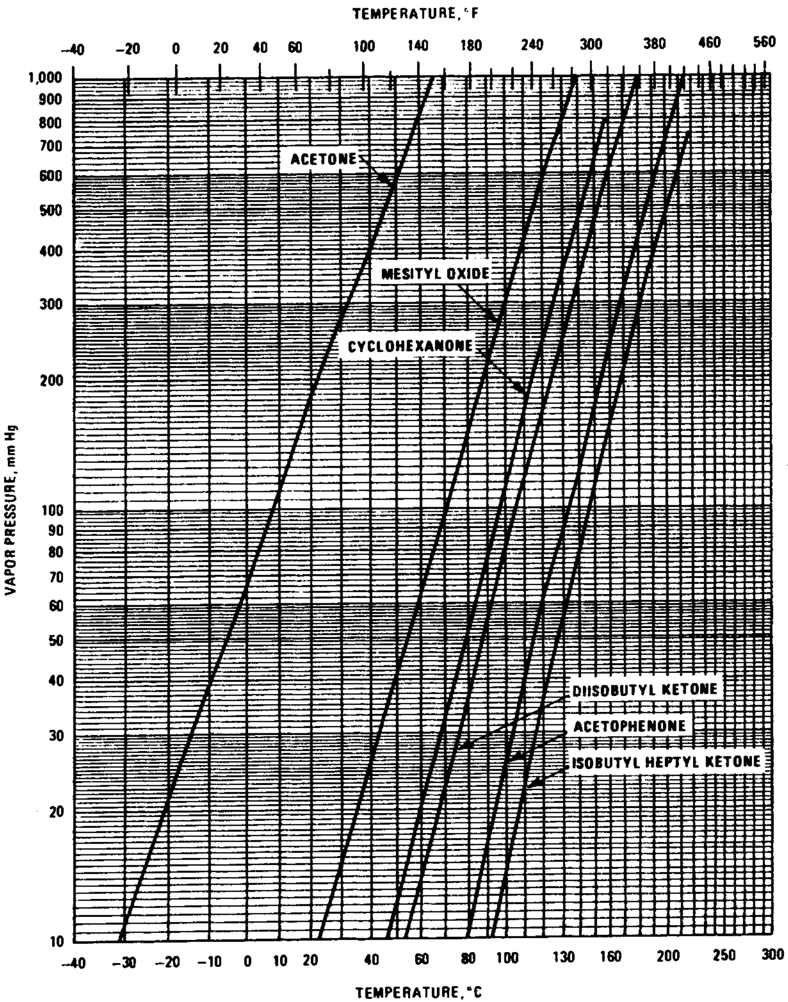
Constant Boiling Mixtures (continued)

Mixture	COMPONENTS: Specific Gravity at 20/20°C	COMPONENTS: Boiling Point at 760 mm Hg, °C	AZEOTROPE: Boiling Point at 760 mm Hg, °C	Composition at 20°C, % by Weight: In Azeotrope	Composition at 20°C, % by Weight: In Upper Layer	Composition at 20°C, % by Weight: In Lower Layer	Relative Volume of Layers at 20°C	Sp Gr at 20/20°C of Azeotrope or Layers
Methyl Ethyl Ketone	0.8060	79.6	78.4	37.5				
Benzene	0.8800	80.1		62.5				0.853
Methyl Ethyl Ketone	0.8060	79.6		26.1	28.1	5.2		
Benzene	0.8800	80.1	68.2	65.1	71.3	0.1	U 92.5	U 0.858
Water	1.0000	100.0		8.8	0.6	94.7	L 7.5	L 0.992
Methyl Ethyl Ketone	0.8060	79.6	45.9	15.3				
Carbon Disulfide	1.2657	46.2		84.7				1.157
Methyl Ethyl Ketone	0.8060	79.6	73.8	29.0				
Carbon Tetrachloride	1.5970	76.7		71.0				1.247
Methyl Ethyl Ketone	0.8060	79.6		22.2	5.5	22.6		
Carbon Tetrachloride	1.5970	76.7	65.7	74.8	0.1	77.3	U 4.0	U 0.993
Water	1.0000	100.0		3.0	94.4	0.1	L 96.0	L 1.313
Methyl Ethyl Ketone	0.8060	79.6	79.9	83.0				
Chloroform	1.4925	61.2		17.0				0.877
Methyl Ethyl Ketone	0.8060	79.6		35.0	37.0	10.0		
Cyclohexane	0.7790	80.7	63.6	60.0	62.4	0.1	U 94.5	U 0.769
Water	1.0000	100.0		5.0	0.6	89.9	L 5.5	L 0.980
Methyl Ethyl Ketone	0.8060	79.6	74.8	66.0				
Ethanol	0.7871	78.3		34.0				0.802
Methyl Ethyl Ketone	0.8060	79.6		75.0				
Ethanol	0.7871	78.3	73.2	14.0				0.832
Water	1.0000	100.0		11.0				
Methyl Ethyl Ketone	0.8060	79.6	64.3	28.3				
Hexane (Commercial)	0.6717	68.7		71.7				0.698
Methyl Ethyl Ketone	0.8060	79.6		22.0	22.5	10.0		
Hexane (Commercial)	0.6717	68.7	55.0	77.0	77.3	0.1	U 99.0	U 0.68(g)
Water	1.0000	100.0		1.0	0.2	89.9	L 1.0	L 0.98(g)
Methyl Ethyl Ketone	0.8060	79.6	77.3	70.0				
Isopropanol	0.7864	82.3		30.0				0.800
Methyl Ethyl Ketone	0.8060	79.6		88.0				
Isopropanol	0.7864	82.3	73.4	1.0				0.834
Water	1.0000	100.0		11.0				
Methyl Ethyl Ketone	0.8060	79.6	73.4	88.0				
Water	1.0000	100.0		12.0				0.834
Methyl Isobutyl Ketone	0.8015	116.1	87.9	76.0	98.4	2.0	U 80.4	U 0.806
Water	1.0000	100.0		24.0	1.6	98.0	L 19.6	L 0.999

Footnotes:

a) Distillation barrier present
b) Homogeneous at 20°C
c) at 4.56 atm
d) at 7.82 atm
e) at 11.6 atm
f) at 20 psig
g) at 30/20°C

Table 12.44: Vapor Pressure of Various Ketones at Different Temperatures *(19)*



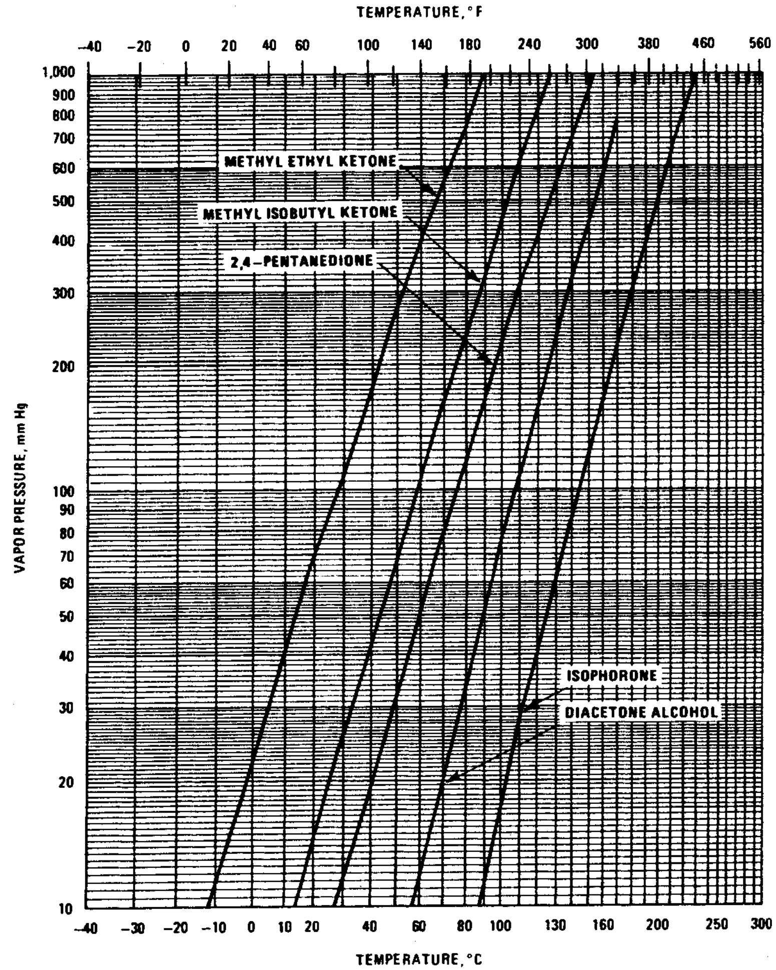
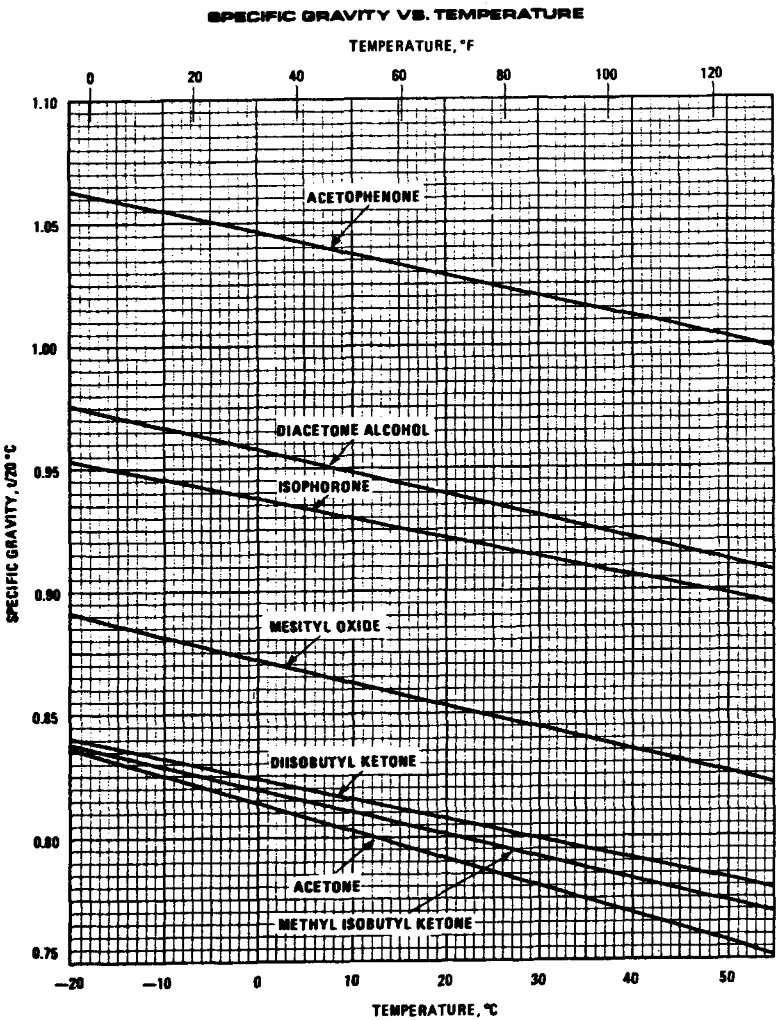
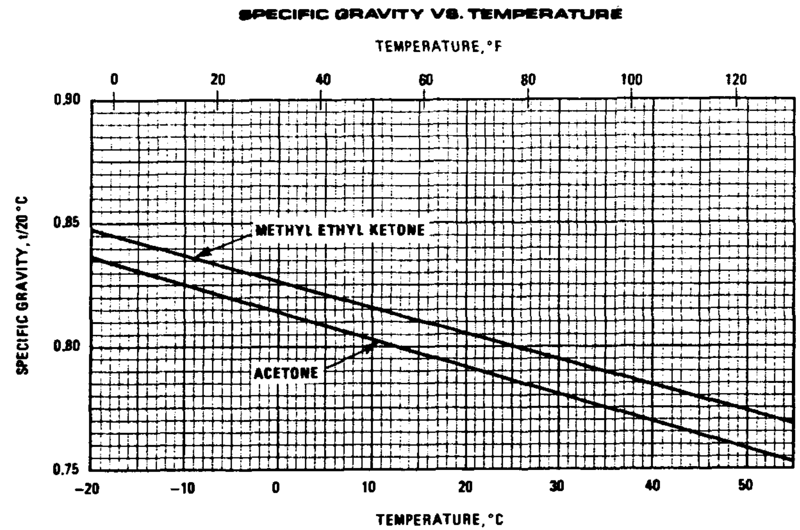


Table 12.45: Specific Gravities of Ketones *(19)*





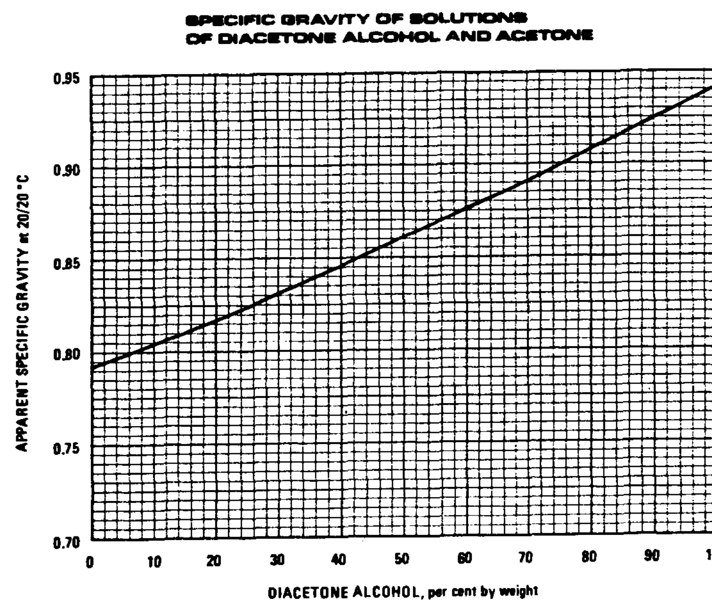


Table 12.46: Solubility of Ketones in Water *(19)*

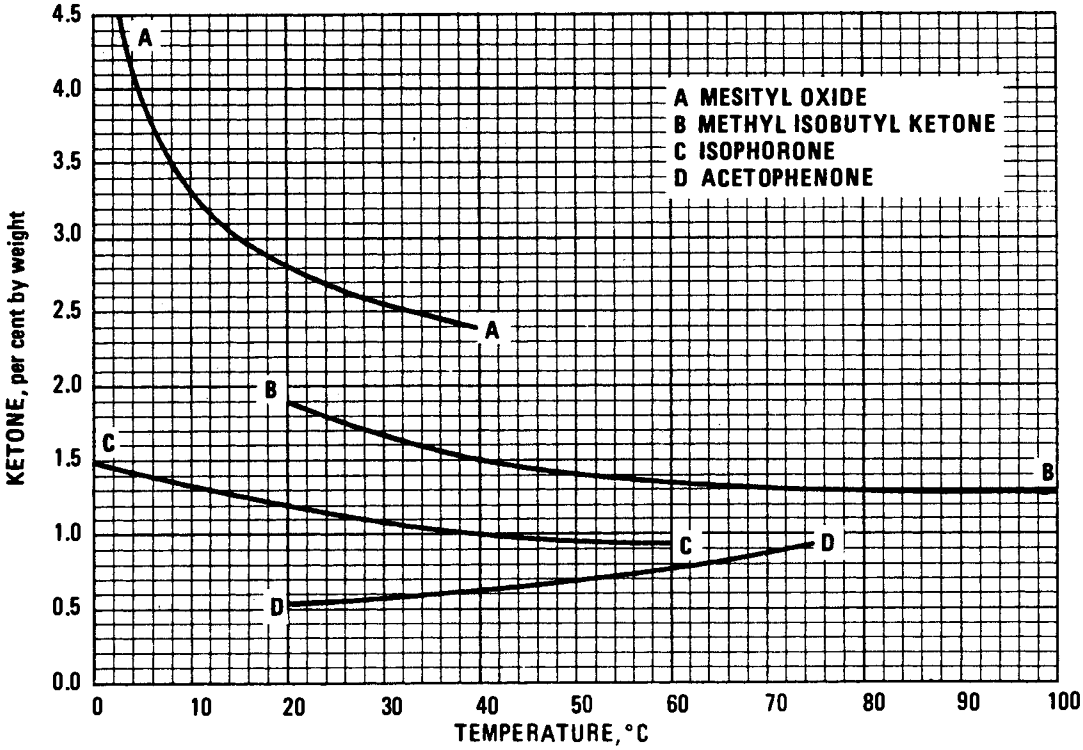


Table 12.47: Solubility of Water in Ketones *(19)*

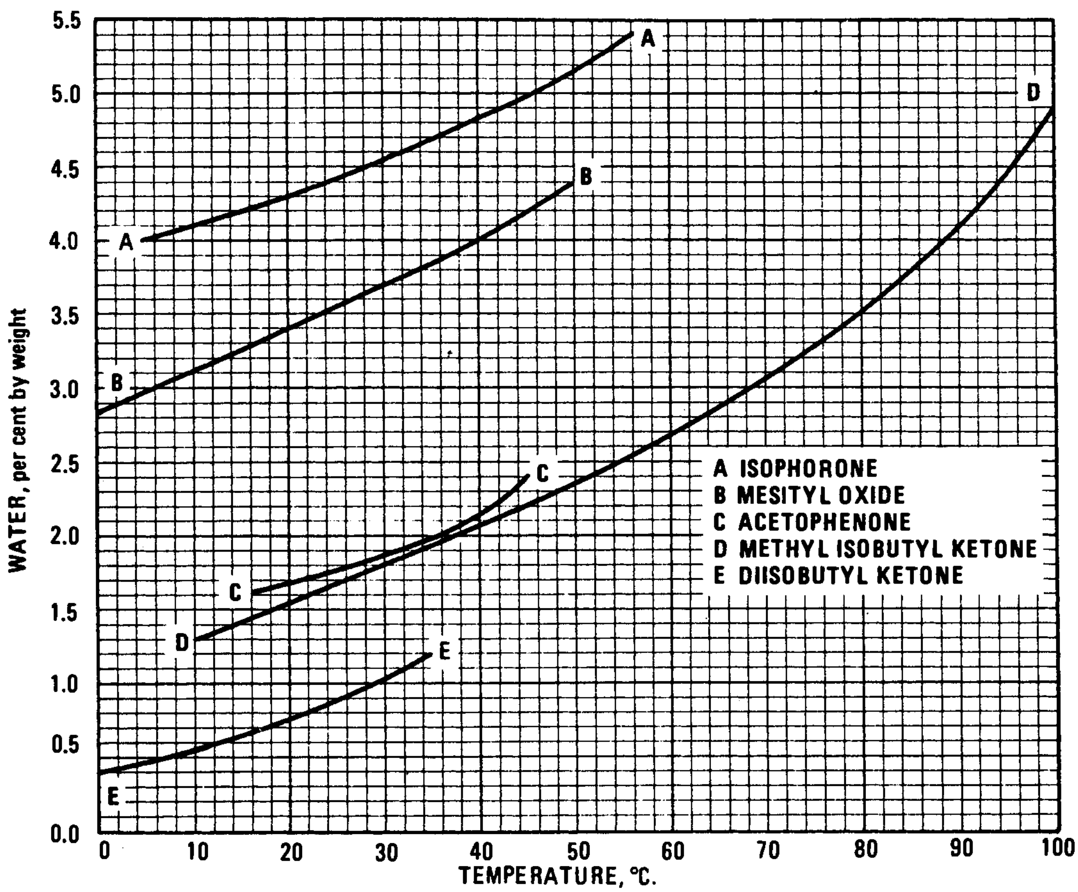


Table 12.48: Relative Evaporation of Ketones—Fast to Intermediate Evaporating Liquids *(19)*

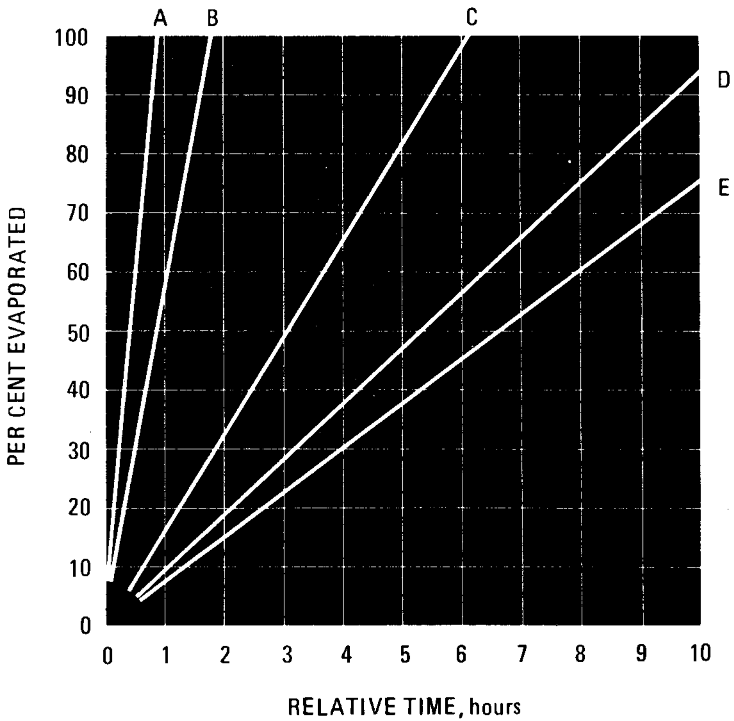


CHART KEY

A Acetone
B Methyl Ethyl Ketone
C Methyl Isobutyl Ketone
D Mesityl Oxide
E 2,4–Pentanedione

Table 12.49: Relative Evaporation of Ketones—Intermediate to Slow Evaporating Liquids *(19)*

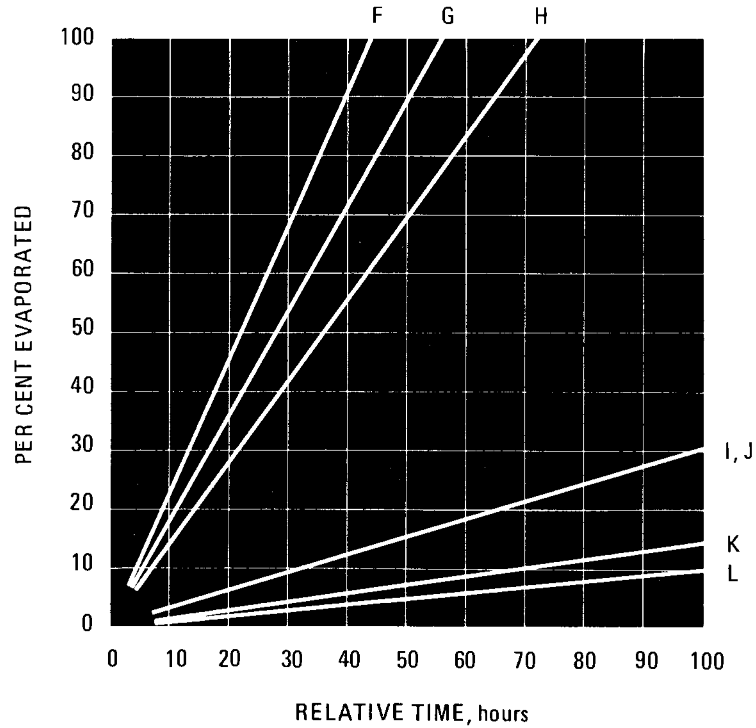
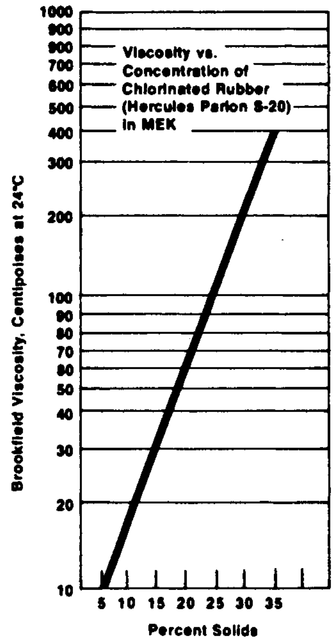


CHART KEY

F Cyclohexanone
G Diisobutyl Ketone
H Diacetone Alcohol
I Acetophenone
J Isophorone
K Isobutyl Heptyl Ketone
L Propiophenone

Table 12.50: Viscosity vs Concentration of Chlorinated Rubber (Hercules PARLON S-20) in MEK *(8)*



Acids

Table 13.1: Acetic Acid *(2)*

Vinegar Acid
Methanecarboxylic Acid
Ethanoic Acid

CH_3COOH

Acetic acid is a colorless liquid with a pungent odor; it is made synthetically from acetylene or by the oxidation of alcohol. It is soluble in water, alcohols, ethyl ether, and other organic solvents. It is used as a precipitant for albumen, casein, and rubber latex. It is also employed in the manufacture of leather, cordage, linoleum, acetate solvents, acetyl derivatives, dyes, matches, printing inks, and polishes, and as an assistant in dyeing processes.

Specifications (Glacial Acetic)

	Standard + Laundry Special	U.S.P. XII	C.P.
Acetaldehyde	0.05% (max.)		
Acidity, as acetic acid	99.5% (min.)	99.5% (min.)	99.8% (min.)
Color	Water-white	Water-white	Water-white
Formic acid	0.2% (max.)		0.00% (max.)
Freezing point	15.6°C (min.)	15.6°C (min.)	16.24°C (min.)
Non-volatile matter		0.0265% (max.)	0.0008% (max.)
Water content	0.5% (max.)	0.5% (max.)	0.2% (max.)
Weight per gallon at 20°C	8.74 lbs.	8.74 lbs.	8.74 lbs.

Table 13.2: Viscosity of Acetic Acid and Acetic Anhydride Mixtures at 15° and 76.5°C *(19)*

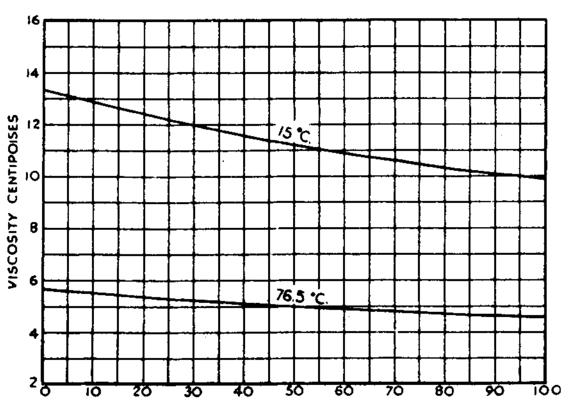


Table 13.3: Butyric Acid *(2)*

Ethylacetic Acid
Butanoic Acid
Propylformic Acid

$CH_3CH_2CH_2COOH$

Butyric acid is a water-white liquid having a characteristically pronounced and highly disagreeable odor. It is soluble in most organic solvents and completely soluble in water. The importance of butyric acid is found in its butyrate, made with alcohols; these compounds are used as flavors because of their pleasant fruity odors. Other uses are in the manufacture of flavor esters, plastics, drugs, in leather tanning and for deliming hides.

Typical Properties and Specifications

Boiling point at 760 mm	163.5°C	Solubility in water at 20°C	Complete
Coefficient of expansion at 20°C	0.001026°C	Solubility of water in solvent at 20°C	Complete
at 55	0.001064	Specific gravity at 20/20°C	0.9595
Color	Water-white	Specific heat	0.514 (20–100°C)
Critical temperature	355°C	Refractive index at 19°C	1.3980
Critical density	0.302	Surface tension at 20°C	26.8 dynes/sq cm
Dissociation constant at 25°C	1.48×10^{-5} recip. ohm	Vapor pressure at 20°C	0.84 mm Hg
Electrical conductivity at 25°C	0.00039×10^{-4} recip. ohm	Viscosity at 25°C	0.01529 poise
Flash point (ASTM open cup)	170°F	Weight per gallon at 20°C	7.985 lbs.
Heat of combustion	5905 cal. (15)/g	Chlorides	None
Heat of fusion	20.1 cal. (15)/g	Distillation range at 760 mm	160–165°C
Heat of vaporization	1.59 cal./g	Purity	99.0% by wt., min.
Melting point	−5.7°C		

Table 13.4: Viscosity of Aqueous Butyric Acid Solution at 25°C *(19)*

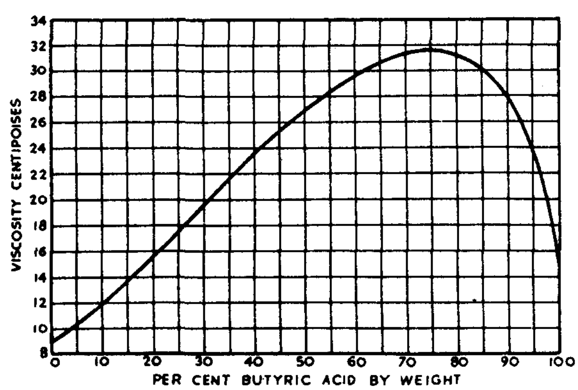


Table 13.5: Butyric Anhydride *(2)*

$(C_3H_7CO)_2O$

Butyric anhydride is a water-white liquid which hydrolyzes to butyric acid in the presence of water. Like butyric acid, it is used in making butyrates, flavors, drugs and tanning agents.

Boiling point at 760 mm.	199.5°C.	Weight per gallon at 20°C.	8.1 lbs.
Color	Water-white	Distillation range at 760 mm.	
Flash point	190°F.	Below 190°C.	None
Melting point	-75°C.	Above 200°C.	None
Specific gravity at 20/20°C.	0.965-0.970	Below 195°C.	Not more than 10%
Vapor pressure at 20°C.	0.37 mm. Hg	Purity	85% by wt., min.

Table 13.6: Solubility of Water in Caproic Acid at Various Temperatures *(19)*

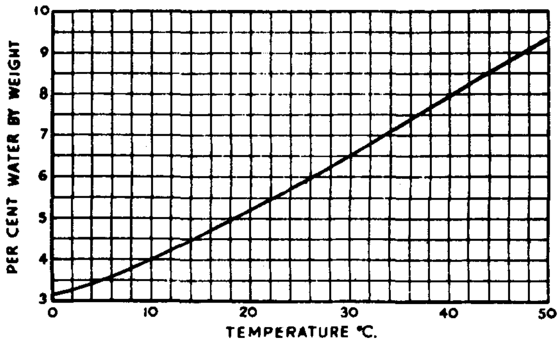


Table 13.7: 2-Ethylbutyric Acid *(2)*

Diethyl Acetic Acid
2-Ethylbutanoic Acid

$(C_2H_5)_2CHCOOH$

2-Ethylbutyric acid is a water-white liquid, similar to butyric acid in most of its properties, except that its odor is less strong and it is not as soluble in water. Its halogenated derivatives are finding use in the manufacture of drugs. Its esters with higher glycols are outstanding vinyl resin plasticizers.

Boiling point at 760 mm.	194°C.	Vapor pressure at 20°C.	0.14 mm. Hg
Flash point	210°F.	Weight per gallon at 20°C.	7.68 lbs.
Solubility in water at 20°C.	0.22% by wt.	Distillation range at 760 mm.	185°-200°C.
Solubility of water in solvent at 20°C.	3.3% by wt.	Purity	90% by wt., min.
Specific gravity at 20/20°C.	0.9225		

Table 13.8: 2-Ethylhexoic Acid *(2)*

Octoic Acid
2-Ethylhexanoic Acid

$CH_3(CH_2)_3CH(C_2H_5)COOH$

This acid possesses a mild odor and a high boiling point. It is important for its metallic esters, the properties of which suggest usefulness as varnish driers. These metallic salts are stable, mild-odored, light-colored compounds, and are soluble in hydrocarbons. The glycol esters of this acid are excellent vinyl resin plasticizers.

Boiling point at 760 mm.	226.9°C.	Vapor pressure at 20°C.	0.03 mm. Hg
Flash point	260°F.	Weight per gallon at 20°C.	7.55 lbs.
Solubility in water at 20°C.	0.25% by wt.	Distillation range at 760 mm.	220°-230°C. (90% distills within this range
Solubility of water in solvent at 20°C.	1.2% by wt.		
Specific gravity at 20/20°C.	0.9077	Purity	95% by wt. min.

Table 13.9: Solubility of Water in Ethylhexoic Acid, Ethylbutyraldehyde and Ethylpropylacrolein *(19)*

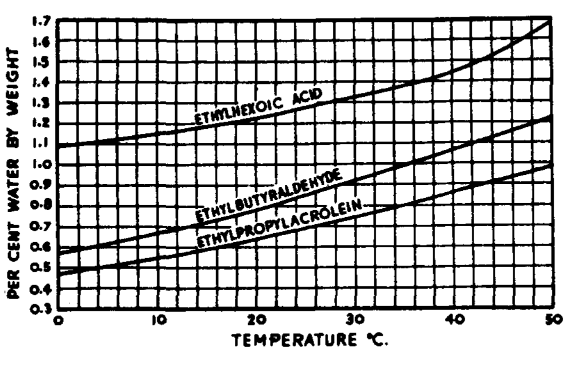
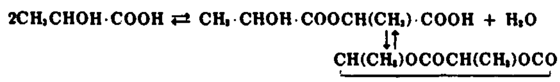


Table 13.10: Lactic Acid *(2)*

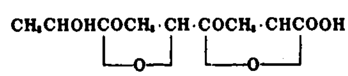
α-Hydroxypropionic Acid $CH_3CHOH \cdot COOH$

Lactic acid, which is among the oldest known organic acids, is obtained from sour milk by the reduction of hexose sugars or by the interaction of acetaldehyde and carbon monoxide. It is miscible with water and many organic reagents. Since it has an asymmetrical carbon atom, lactic acid exists in two optical isomeric forms. Peckham states that "the nomenclature used to designate the isomeric forms was, until recently, very confusing. The form of the acid commonly known as sarco-lactic, the form occurring in blood, has (+) rotation but the l configuration. It is therefore correctly designated as l(+) lactic acid and its mirror image as d(-) lactic acid. The salts of the l(+) form are levorotatory and the salts of the d(-) form are dextrorotatory. Because of the low optical rotatory power of the free acids, rotation of the pure acid or its simple salts is not a suitable criterion for establishing the optical form of the acids, or the percentage composition in case of a mixture".

Commercial lactic acid has been determined to be a mixture of α-hydroxypropionic acid, lactyllactic acid, and water. When dilute lactic acid is concentrated, two molecules of lactic acid unite to form lactyllactic acid and water. The lactyllactic acid splits off from the water.

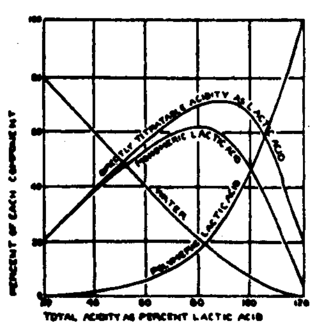


Polylactyllactic acids may also be formed by loss of water between the carboxyl and the alcohol groups, thus:



dilactyllactic acid

The conditions which affect the production of a lactic acid solution from lactyllactic acid are temperature, concentration and age of solution.

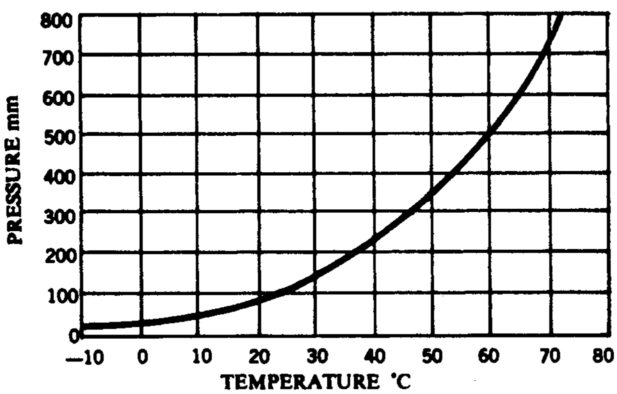


A graph showing the Composition of Aqueous Lactic Acid Systems at Equilibrium and at Progress States of Dehydration.

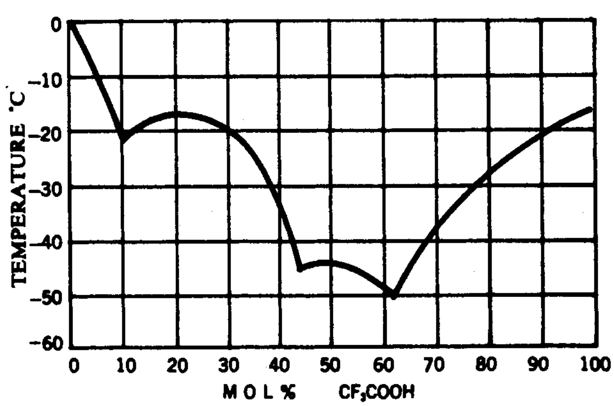
Table 13.11: Trifluoroacetic Acid *(25)*

CF_3CO_2H Mol. Wt.	114.03
Boiling Point	72.5°C
Water Azeotrope (20.6% water)	105.5°C *(1)*
Freezing Point	-15.36°C *(1,2)*
Density at 25°C	1.4844 g/ml
	12.4 lb/gal
Vapor Pressure 0°C	28.8 mm *(3)*
25°C	107 mm
Heat of Vaporization	7949 cal/mol *(3)*
	125.5 Btu/lb
Viscosity at 25°C	0.813 cp *(4)*
Dielectric Constant at 25°C	42.1 ϵ *(5)*
Conductivity at 25°C	0.026 10^5/cm ohm *(4)*
Surface Tension at 26°C	13.44 dynes/cm *(6)*

(1) Swarts, F., Bull. Acad. Roy. Belg. Classe sci., 8, 343 (1922).
(2) Cady, H.H. and Cady, G.E., J. Am. Chem. Soc., 76, 915 (1954).
(3) Taylor, M.D. and Templeman, M.B., J. Am. Chem. Soc., 78, 2950 (1956).
(4) Fialkov, Y.Y. and Zhikarev, V.S., Zh. Obshch. Khim., 33, 3466, 3471, 3790 (1963).
(5) Simons, J.H. and Lorentzen, K.E., J. Am. Chem. Soc., 72, 1426 (1950).
(6) Jasper, J.J. and Wedlick, H.L., J. Chem. Eng. Data, 9, 446 (1964).



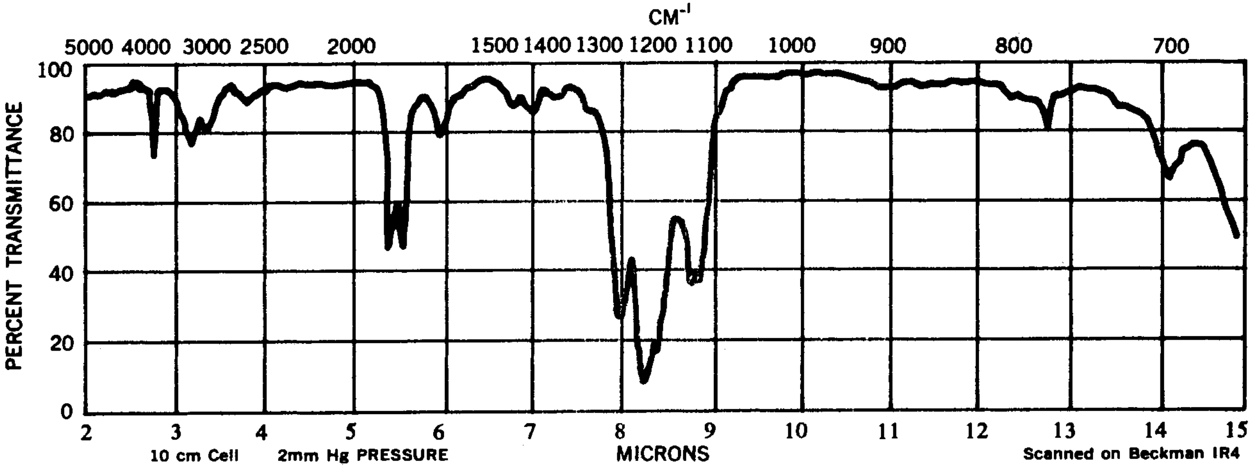
VAPOR PRESSURE OF TRIFLUOROACETIC ACID



FREEZING POINTS WATER—TRIFLUOROACETIC ACID SYSTEM

(continued)

Table 13.11: (continued)



INFRARED SPECTRUM OF TRIFLUOROACETIC ACID

Properties of Derivatives of Trifluoroacetic Acid

Compound	Formula	Boiling Point °C	Melting Point °C
Trifluoroacetic Anhydride	$(CF_2CO)_2O$	40	–65
Methyl Trifluoroacetate	$CF_3CO_2CH_3$	43	
Ethyl Trifluoroacetate	$CF_3CO_2C_2H_5$	62	
Trifluoroacetamide	CF_3CONH_2	163	75
Trifluoroacetonitrile	CF_3CN	–64	
Trifluoroacetyl Chloride	CF_3COCl	–19	
Trifluoroacetyl Bromide	CF_3COBr	–5	–130
Trifluoroacetaldehyde	CF_3CHO	–19	
Trifluoroacetaldehyde Hydrate	$CF_3CH(OH)_2$	102-5	68-70

(continued)

Table 13.11: (continued)

SOLUBILITY OF INORGANIC ACIDS

MISCIBLE	INSOLUBLE
HCl, $HClO_4$ HF, HNO_3, H_2SO_4	H_3PO_4

SOLUBILITY OF SALTS IN 100 GRAMS OF TRIFLUOROACETIC ACID AT ABOUT 25°C

Over 10 g	1-10 g	0.1-1 g	Less than 0.1 g
CsCl K_3PO_4 K_2SO_4 NH_4NO_3	AgF, CrO_3, $FeCl_3$, KCl $KCrO_4$, KF, KI $KMnO_4$, KNO_3, NaCl, $NaCrO_4$, NaI NaF, $NaNO_3$, Na_3PO_4, Na_2SO_4	$BaCl_2$, $BeCl_2$ $CrCl_3$ $Cr_2(SO_4)_3$ MgF_2 NiF_2	AgCl, $AlCl_3$ $BaSO_4$ CaF_2, FeF_3 $KClO_4$ $NaClO_4$, PbF_2

SOLUBILITY OF METAL TRIFLUOROACETATES IN TRIFLUOROACETIC ACID AT 30°C

Metal Salt	Al	Ba	Ca	Cu^{+2}	Hg^{+2}	K	Mg	Na	Ni	Fe^{+3}*
g Salt/100 g acid	0.01	42	6.3	20	50	50	0.57	13	16	1.2

* Ref (38)

It is interesting to note that $Si(O_2CCF_3)_4$, $TiO(O_2CCF_3)_2$, $Zr(O_2CCF_3)_4$ and $Th(O_2CCF_3)_4$ have been prepared (77). The silicon compound exhibits covalent character.

SOLUBILITY OF GASES AT ABOUT 26°C; PARTIAL PRESSURES 650 mm Hg (38)
(Units are ml. gas dissolved in one ml. liquid)

Gas	Cl_2	CO	CO_2	HBr	HCl	H_2S	N_2	O_2	SO_2
Trifluoroacetic Acid	9.3	0.0	3.5	6.6	4.1	8.6	0.1	0.2	23
Water	2.1	0.02	0.8	580	423	2.5	0.02	0.03	36

Table 13.12: Vapor Pressure of Organic Acids and Anhydrides at Various Temperatures *(19)*

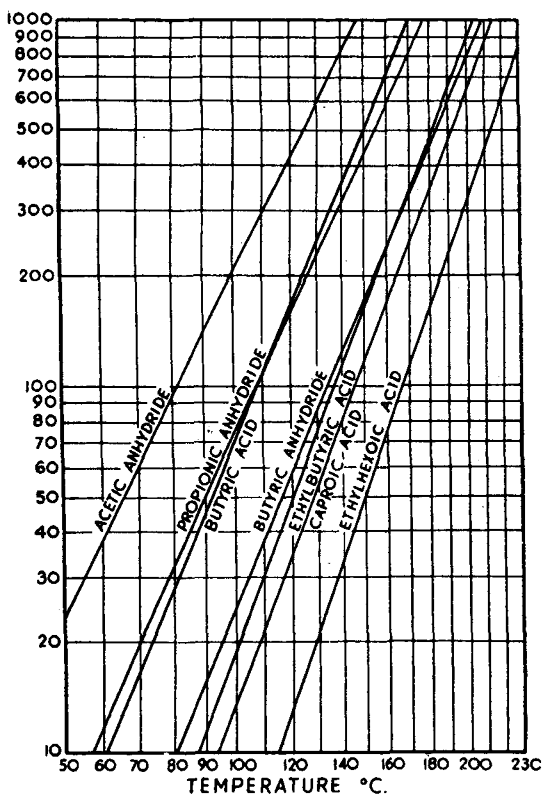


Table 13.13: Fatty Acid Composition of Various Fats and Oils *(26)*

	BUTYRIC	CAPROIC	CAPRYLIC	CAPRIC	LAURIC	LAUROLEIC	MYRISTIC	MYRISTOLEIC	PENTADECANOIC	PALMITIC	PALMITOLEIC	MARGARIC	STEARIC	OLEIC	LINOLEIC	LINOLENIC	RICINOLEIC	DIHYDROXYSTEARIC	LICANIC	ELEOSTEARIC	ARACHIDIC	EICOSENOIC	EICOSAPOLYENOIC	BEHENIC	ERUCIC (DOCOSENOIC)	DOCOSAPOLYENOIC	LIGNOCERIC	TETRACOSENOIC	TETRACOSAPOLYENOIC	IODINE VALUE	SAPONIFICATION VALUE	TITER —°C.
BABASSU	—	—	6.0	5.5	45.0	—	16.5	—	—	7.0	—	—	3.0	14.5	1.5	—	—	—	—	—	—	1.0	—	—	—	—	—	—	—	12-18	247-251	22-26
BUTTERFAT	3.0	1.0	1.5	3.0	3.5	—	12.0	1.5	1.0	28.0	3.0	—	13.0	28.5	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25-42	210-235	33-38
CASTOR	—	—	—	—	—	—	—	—	—	1.5	—	—	0.5	5.0	4.0	0.5	87.5	0.5	—	—	0.5	—	—	—	—	—	—	—	—	81-91	177-187	1-3
COCOA BUTTER	—	—	—	—	—	—	0.5	—	—	25.0	—	—	34.5	36.5	3.0	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	35-40	190-200	45-50
COCONUT	—	0.5	7.0	6.0	48.0	—	19.0	—	—	9.0	—	—	3.0	6.0	1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8-12	250-260	20-24
CORN	—	—	—	—	—	—	—	—	—	12.0	—	—	2.0	25.0	60.0	0.5	—	—	—	—	0.5	—	—	—	—	—	—	—	—	118-128	186-194	14-20
COTTONSEED	—	—	—	—	—	—	1.0	—	—	23.0	0.5	—	2.5	16.5	57.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	103-113	189-199	30-37
HERRING	—	—	—	—	—	—	7.0	—	—	12.0	10.0	—	0.5	8.0	13.0	—	—	—	—	—	—	25.5		—	24.0		—	—	—	125-145	180-193	23-27
LARD	—	—	—	—	—	—	1.5	—	—	25.0	3.0	0.5	13.0	45.5	10.5	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	58-68	192-202	34-43
LINSEED	—	—	—	—	—	—	—	—	—	6.0	—	—	3.5	20.0	14.5	56.0	—	—	—	—	—	—	—	—	—	—	—	—	—	180-195	188-196	19-21
MENHADEN	—	—	—	—	—	—	9.0	0.5	0.5	19.0	16.0	0.5	5.5	24.5	24.5		—	—	—	—	—	15.0		—	9.0		—	0.5		140-180	188-196	31-33
MUSTARD SEED (MONTANA)	—	—	—	—	—	—	—	—	—	3.0	0.5	—	6.5	22.0	22.5	15.5	—	—	—	—	0.5	11.5	—	—	18.0	—	—	—	—	114-128	176-184	6-10
NEATSFOOT	—	—	—	—	—	0.5	1.0	0.5	—	20.5	6.0	—	4.5	56.5	9.5	—	—	—	—	—	0.5		—	—	0.5		—	—	—	65-75	190-199	20-30
OITICICA	—	—	—	—	—	—	—	—	—	6.0	—	—	5.0	6.0	5.0	—	2.0		76.0	—	—	—	—	—	—	—	—	—	—	140-160	188-196	17-21
OLIVE	—	—	—	—	—	—	—	—	—	13.0	1.0	—	2.5	74.0	9.0	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	79-89	188-196	17-26
PALM	—	—	—	—	—	—	1.0	—	—	43.5	—	—	4.5	40.0	11.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	45-55	195-205	40-47
PALM KERNEL	—	—	3.5	3.5	46.5	—	16.5	—	—	8.5	—	—	2.5	14.5	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14-24	245-255	20-28
PEANUT (SOUTHWEST)	—	—	—	—	—	—	—	—	—	11.0	—	—	2.5	50.0	30.5	1.0	—	—	—	—	1.0	—	—	3.0	—	—	1.0	—	—	93-98	188-196	28-34
PEANUT (WEST COAST)	—	—	—	—	—	—	—	—	—	12.5	—	—	3.0	38.5	38.0	1.5	—	—	—	—	1.5	—	—	3.5	—	—	1.5	—	—	96-101	188-196	26-32
PERILLA	—	—	—	—	—	—	—	—	—	8.0	—	—	—	16.0	14.0	62.0	—	—	—	—	—	—	—	—	—	—	—	—	—	193-208	188-197	12-19
RAPESEED (HIGH-ERUCIC)	—	—	—	—	—	0.5	—	—	—	4.0	—	—	0.5	12.5	14.5	16.5	—	—	—	—	—	—	—	—	51.5	—	—	—	—	97-104	169-179	11-15
RAPESEED (MONTANA)	—	—	—	—	—	—	—	—	—	3.0	—	—	1.5	32.0	19.0	10.0	—	—	—	—	—	10.5	—	0.5	23.5	—	—	—	—	104-110	170-180	11-15
RICE BRAN	—	—	—	—	—	—	0.5	—	—	17.0	—	—	2.5	45.5	32.0	1.0	—	—	—	—	0.5	—	—	—	—	—	1.0	—	—	92-109	184-195	26-28
SAFFLOWER	—	—	—	—	—	—	—	—	—	6.5	—	—	2.5	11.5	79.0	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	138-145	186-195	15-18
SARDINE	—	—	—	—	—	—	6.0	—	—	11.5	12.0	—	2.5	11.5	11.5	—	—	—	—	—	—	25.5		—	19.5		—	—	—	160-190	188-196	28-32
SESAME	—	—	—	—	—	—	—	—	—	9.0	—	—	6.0	41.5	43.0	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	106-113	188-196	20-25
SOYBEAN	—	—	—	—	—	—	—	—	—	11.0	—	—	4.0	21.0	55.5	8.5	—	—	—	—	—	—	—	—	—	—	—	—	—	125-135	188-196	20-22
SPERM-BODY FATTY ACIDS	—	—	—	—	1.0	—	5.0	4.0	—	6.5	26.5	—	—	37.0	—	—	—	—	—	—	—	19.0	—	—	1.0	—	—	—	—	76-88	122-130	8-14
SPERM-HEAD FATTY ACIDS	—	—	—	3.0	16.0	4.0	14.0	14.0	—	8.0	15.0	—	2.0	17.0	—	—	—	—	—	—	—	7.0	—	—	—	—	—	—	—	55-70	140-144	12-18
SUNFLOWER	—	—	—	—	—	—	0.5	—	—	6.5	—	—	4.0	17.0	72.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	128-138	186-196	16-20
TALL OIL (Distilled Fatty Acids)	—	—	—	—	—	—	—	—	—	1.0	0.5	—	1.5	50.5	46.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	128-133	186-196	1-8
TALLOW	—	—	—	—	—	—	3.5	1.0	0.5	25.5	4.0	2.5	19.5	41.0	2.5	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	40-50	192-202	40-46
TUNG OIL	—	—	—	—	—	—	—	—	—	4.0	—	—	1.0	8.5	3.5	3.0	—	—	—	80.0	—	—	—	—	—	—	—	—	—	160-175	189-195	34-42
WHALE	—	—	—	—	—	—	8.0	2.0	—	17.0	13.0	—	2.0		39.0		—	—	—	—	—	12.5		—	6.5		—	—	—	110-140	185-195	22-24
NUMBER OF CARBON ATOMS	4	6	8	10	12	12	14	14	15	16	16	17	18	18	18	18	18	18	18	18	20	20	20	22	22	22	24	24	24			
NUMBER OF DOUBLE BONDS	0	0	0	0	0	1	0	1	0	0	1	0	0	1	2	3	1	0	3	3	0	1	2-5	0	1	2-5	0	1	2-5			
MOLECULAR WEIGHT	88	116	144	172	200	198	228	226	242	256	254	270	284	282	280	278	298	316	292	278	312	310	—	340	338	—	368	366	—			
NEUTRALIZATION VALUE	636	483	389	325	280	282	245	247	231	216	220	207	197	198	200	201	187	177	191	201	179	180	—	164	165	—	152	153	—			
IODINE VALUE	0	0	0	0	0	128	0	112	0	0	99	0	0	89	181	273	85	0	260	273	0	81	—	0	74	—	0	69	—			
BOILING POINT —°C @ 5 mm Hg	50.0	86.5	113.5	137.0	158.0	—	178.0	—	187.0	197.0	—	206.0	214.0	209.0	—	—	—	—	—	—	233.0	—	—	247.0	—	—	255.0	—	—			
MELTING POINT —°C	−8.0	−3.4	16.7	31.6	44.2	—	53.9	—	52.3	63.1	0.5	61.3	69.6	13.4	−5.0	<−10.0	5.0	141.0	74.0-75.0	—	75.3	—	—	79.9	34.7	—	84.2	—	—			

Table 13.14: Arizona Chemical ACTINOL Tall Oil Fatty Acids *(5)*

	COLOR GARDNER 1963	ACID VALUE	SAPONIFI-CATION VALUE	IODINE VALUE (WIJS)	MOISTURE %	ASH %	ROSIN ACIDS %	UNSAPONI-FIABLES %	FATTY ACIDS TOTAL %	LINOLEIC NON-CON-JUGATED
FA-1	5	194	197	131	< 0.1	< 0.01	4.5	2.7	92.8	34
FA-1 Special	4 +	195	198	131	< 0.1	< 0.01	2.8	2.0	95.2	35
FA-2	3 +	197	199	130	< 0.1	< 0.01	0.9	1.3	97.8	37
FA-3	3 -	198	200	130	< 0.1	< 0.01	0.5	0.7	98.8	38
EPG	1 +	198	200	130	< 0.1	< 0.01	0.5	0.5	99.0	38
736	7	189	-	-	< 0.1	< 0.01	7.5	5.5	87.0	0
746	4	198	-	90	< 0.1	< 0.01	1.0	1.5	97.5	0

	LINOLEIC CONJUGATED	OLEIC %	SATURATED %	OTHERS BY DIFFER-ENCE, %	SPECIFIC GRAVITY 25°/25° C	WEIGHT PER GAL. 25° C, LBS.	VISCOSITY GARDNER-HOLDT 25° C	VISCOSITY CPS 25° C	FLASH POINT CLOSED CUP ° F
FA-1	9	44	5	8	0.906	7.53	A	20	> 200
FA-1 Special	9	47	3	6	0.902	7.50	A	20	> 200
FA-2	7	50	2	4	0.898	7.47	A	20	> 200
FA-3	7	50	2	3	0.897	7.45	A	20	> 200
EPG	7	51	2	2	0.897	7.45	A	20	> 200
736	11	61	10	18	0.900	7.48	-	-	> 200
746	13	75	5	7	0.905	7.52	-	-	> 200

Table 13.15: Eastman Chemicals Acids and Anhydrides *(41)*

	Form	Color Pt-Co Max	Specific Gravity @ 20°/20°C	Boiling Point °C	Freezing Point °C	Flash Point TOC °C (°F)	Fire Point °C (°F)	Assay Min Wt %
Glacial Acetic Acid[a,b,c,d] (Ethanoic Acid) CH_3COOH	Liquid	—	1.05	118	17	43 (109)	64 (148)	99
Acetic Anhydride[d] (Acetyl Oxide) $(CH_3CO)_2O$	Liquid	—	1.08	140	-73	56 (132)	58 (137)	99
Butyric Acid (Ethyl Acetic Acid) C_3H_7COOH	Liquid	15	0.96	164	-8	71 (160)	75 (167)	99
Butyric Anhydride $(C_3H_7CO)_2O$	Liquid	—	0.97	195	-73	84 (183)	87 (189)	98
Crotonic Acid (2-Butenoic Acid) $CH_3CH{:}CHCOOH$	Solid	15 (APHA)	0.96 (80°/4°C)	185	70	94 (202) COC	97 (207)	99
2-Ethylhexoic Acid (2-Ethylhexanoic Acid) $C_4H_9CH(C_2H_5)COOH$	Liquid	25	0.91	223	-118	118 (245) COC	127 (260)	99
Isobutyric Acid (2-Methylpropanoic Acid) $(CH_3)_2CHCOOH$	Liquid	10	0.95	155	-47	62 (143)	67 (152)	99
Isobutyric Anhydride $C_8H_{14}O_3$	Liquid	—	0.95	182	-54	72 (161)	74 (166)	98
Propionic Acid[a,b,c] C_2H_5COOH	Liquid	10	0.99	141	-22	54 (130)	58 (137)	99
Propionic Anhydride $(C_2H_5CO)_2O$	Liquid	—	1.01	167	-45	66 (151)	66 (151)	98

[a]*Available in food grade*
[b]*Kosher certified*
[c]*Available in feed grade*
[d]*Available in reagent grade*

Table 13.16: Halocarbon Products BIOGRADE Trifluoroacetic Acid *(25)*

SPECIFICATIONS:

Assay by titration	99.9% Min.
Trifluoroacetic Anhydride	nil
Water	0.05% Max.
Trace Impurities (Maximums)	
Chloride	0.001%
Fluoride	0.001%
Sulfate	0.001%
Iron (Fe)	0.0001%
Residue after evaporation	0.0002%
Color (Platinum-Cobalt Scale)	5 Max.
Ultraviolet Absorbance Maxima (0.1% in distilled water vs. distilled water in 1 cm cell path)	
at 230 nm	0.15%
at 254 nm	0.01%

Table 13.17: EMERY Fatty and Dibasic Acids *(63)*

Dimer, Trimer and Polybasic Acids

Specifications			Comparative Typical Composition[1]					
			Short-Path Methyl Ester Distillation			High Pressure Liquid Chromatography		
	Acid Value	Color 1963 Gardner, max.	Mono	Di	Poly	Mono	Di	Poly
Empol® 1010 Dimer Acid (polymer grade)	194-200	1	0	97	3	4	94	2
Empol 1014 Dimer Acid	194-198	5	1	95	4	4	91	5
Empol 1016 Dimer Acid	190-198	6	1	80	19	6	76	18
Empol 1018 Dimer Acid	190-198	8	Tr	83	17	6	79	15
Empol 1022 Dimer Acid	189-197	8	3	75	22	9	77	14
Empol 1024 Dimer Acid	190-198	8	Tr	75	25	8	77	15
Empol 1040 Trimer Acid	175-192	—	—	7	93	2	18	80
Empol 1041 Trimer Acid	161-181	11	—	10	90	3	35	62
Empol 1052 Polybasic Acid	250-265[2]	dark	—	—	—	3[3]	34[3]	63[3]

[1]Short path methyl ester fractionation measures the relative molecular size of the various components of these acids. High pressure liquid chromatography (HPLC) separates components according to their functionality.

[2]Not a specification.

[3]By thin layer chromatography. This method determines composition according to functionality.

Food Grade[1] Fatty Acids

Specifications					Typical Composition[2]									
					Saturated Acids					Unsaturated Acids				
	Titer, °C	Iodine Value max.	Color % Trans. 440/550 nm., min.	Acid Value	Myristic $C_{14}H_{28}O_2$	Pentadecanoic $C_{15}H_{30}O_2$	Palmitic $C_{16}H_{32}O_2$	Margaric $C_{17}H_{34}O_2$	Stearic $C_{18}H_{36}O_2$	Myristoleic $C_{14}H_{26}O_2$	Palmitoleic $C_{16}H_{30}O_2$	Oleic $C_{18}H_{34}O_2$	Linoleic $C_{18}H_{32}O_2$	Linolenic $C_{18}H_{30}O_2$
Emersol® 6320 DP Stearic Acid	53.9-54.7	3.5-5.0	88/99	205-210	2.5	0.5	50	1	40			6		
Emersol 6332 NF TP Stearic Acid[3,4]	54.5-55.5	0.5	93/99	205-211	1.5	0.5	50	1	47					
Emersol 6349 Stearic Acid	59.0-60.5	0.5	88/99	203-206	3	0.5	26.5	1	69			Tr		
Emersol 6351 Stearic Acid[5]	65-68	1.0	84/98	196-201	1	Tr	7.5	2.5	88			1		
Emersol 6313 NF Low-titer Oleic Acid[3]	6 max.	88-93	75/98	201-204	3	Tr	5	1	Tr	3	6	75	6	1
Emersol 6321 NF Low-titer White Oleic[3]	6 max.	87-92	85/99	201-204	3	Tr	5	1	Tr	3	6	75	6	1
Emersol 6333 NF LL Oleic Acid[3,6]	8-10	86-91	85/99	200-204	3	Tr	6.5	1	1.5	3	5.5	73.5	5.5	0.5

[1]Meet the requirements of Federal Food Additive Regulation Section 21CFR 172.860.

[2]Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.

[3]USP XXI/NF XVI.

[4]Powdered grade also available.

[5]Emersol 7051 Kosher Grade available.

[6]LL (low-linoleic content) oleic: polyunsaturate 6% max.

(continued)

Table 13.17: (continued)

Coconut Fatty Acids

	Specifications					Typical Composition[1]							
	Titer, °C	Iodine Value	Color % Trans. 440/550 nm., min.	Color Gardner 1963, max.	Acid Value	Caprylic $C_8H_{16}O_2$	Capric $C_{10}H_{20}O_2$	Lauric $C_{12}H_{24}O_2$	Myristic $C_{14}H_{28}O_2$	Palmitic $C_{16}H_{32}O_2$	Stearic $C_{18}H_{36}O_2$	Oleic $C_{18}H_{34}O_2$	Linoleic $C_{18}H_{32}O_2$
Emery® 621 Coconut Fatty Acid	23-27	5-16	30/80	5[2]	258-268	4	5	48	20	10	2	10	1
Emery 622 Coconut Fatty Acid	22-26	5-10	65/96	2[2]	268-276	7	6	48	19	9	2	8	1
Emery 625 Partially Hydrogenated Coconut Fatty Acid	23-25	5.0 max.	85/98	1	269-273	7	6	49	19	9	7	3	
Emery 626 Low IV Ultra Coconut Fatty Acid[3]	**23-26**	**1.0 max.**	**85/99**	**1**	**270-276**	**7**	**6**	**51**	**18**	**10**	**7**	**1**	
Emery 627 Low IV, Stripped, Ultra Coconut Fatty Acid	**28-32**	**1.0 max.**	**90/98**	**1**	**252-258**		**1**	**55**	**22**	**11**	**10**	**1**	
Emery 629 Stripped, Coconut Fatty Acid	27-30	6-10	88/98	1	253-259		1	55	23	12	3	5	

[1]*Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.*
[2]*Typical property.*
[3]*Emery 7026 Kosher Grade available.*

Isostearic Acids

	Specifications			
	Titer, °C, max.	Iodine Value	Color % Trans. 440/550, nm., min.	Acid Value
Emersol® 871 Isostearic Acid	10	12 max.	30/85	175 min.
Emersol 875 Isostearic Acid	10	3 max.	85/98	187-197

Oleic Acids

	Specifications				Typical Composition[1] — Saturated Acids						Typical Composition[1] — Unsaturated Acids				
	Titer, °C	Iodine Value	Color % Trans. 440/550 nm., min.	Acid Value	Lauric $C_{12}H_{24}O_2$	Myristic $C_{14}H_{28}O_2$	Pentadecanoic $C_{15}H_{30}O_2$	Palmitic $C_{16}H_{32}O_2$	Margaric $C_{17}H_{34}O_2$	Stearic $C_{18}H_{36}O_2$	Myristoleic $C_{14}H_{26}O_2$	Palmitoleic $C_{16}H_{30}O_2$	Oleic $C_{18}H_{34}O_2$	Linoleic $C_{18}H_{32}O_2$	Linolenic $C_{18}H_{30}O_2$
Emersol® 210 Oleic Acid	7-12	87-95	2/30	197-204	Tr	3	Tr	5	1	1	4	6	71	8	1
Emersol 213 NF Low-titer Oleic Acid[2,3]	5 max.	88-95	56/86	199-204	Tr	3	Tr	5	1	Tr	3	6	73	8	1
Emersol 221 NF Low-titer White Oleic Acid[2,3]	5 max.	88-95	77/98	199-204	Tr	3	Tr	4	1	Tr	3	7	73	8	1
Emersol 223 NF Ultra Oleic Acid[3]	**5 max.**	**88-95**	**85/99**	**199-204**	**Tr**	**3**	**Tr**	**4**	**1**	**Tr**	**3**	**7**	**73**	**8**	**1**
Emersol 233 LL Oleic Acid[4]	6 max.	86-90	78/99	200-204	Tr	3	Tr	4	1	Tr	3	11	74	4	Tr

[1]*Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.*
[2]*Corresponding food grade products available*
[3]*For external use only, USP XXI/NF XVI.*
[4]*LL (low-linoleic content) oleic: polyunsaturates 5% max.*

(continued)

Table 13.17: (continued)

Short-Chain Acids[2]

	Specifications				Typical Composition[1]					
	Titer, °C	Iodine Value max.	Color % Trans. 440/550 nm., min.	Acid Value	Caproic $C_6H_{12}O_2$	Caprylic $C_8H_{16}O_2$	Capric $C_{10}H_{20}O_2$	Lauric $C_{12}H_{24}O_2$	Myristic $C_{14}H_{28}O_2$	Palmitic $C_{16}H_{32}O_2$
Emery® 657 Caprylic Acid	14-16	0.2	88/99	385-390	Tr	99	1			
Emery 658 Caprylic-Capric Acid	1-6	0.3	88/99	356-366	3	56	40	1		
Emery 659 Capric Acid	28-31	0.5	88/99	322-326		1	97	2		
Emery 650 Lauric Acid	33-35	0.4	85/97	268-272				71	28	1
Emery 651 Lauric Acid	41-43	0.2	90/98	276-282		Tr	1	96	3	
Emery 652 Lauric Acid	43 min.	0.2	90/98	277-281		Tr	0.3	99	0.7	
Emery 655 Myristic Acid	52.0-53.5	0.5	90/99	243-246				1	97	2

[1]Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.
[2]Kosher Grades of these acids are available.

Stearic and Palmitic Acids

	Specifications				Typical Composition[1]								
					Saturated Acids						Unsaturated Acids		
	Titer, °C	Iodine Value	Color % Trans. 440/550 nm., min.	Acid Value	Myristic $C_{14}H_{28}O_2$	Pentadecanoic $C_{15}H_{30}O_2$	Palmitic $C_{16}H_{32}O_2$	Margaric $C_{17}H_{34}O_2$	Stearic $C_{18}H_{36}O_2$	Arachidic $C_{20}H_{40}O_2$	Palmitoleic $C_{16}H_{30}O_2$	Oleic $C_{18}H_{34}O_2$	Linoleic $C_{18}H_{32}O_2$
Emersol® 110 Stearic Acid	52.8-53.5	8-12	60/94	205-210	2.5	0.5	50	2	35			9	1
Emersol 120 Stearic Acid[2]	53.7-54.7	5-7	88/99	205-210	2.5	1	50	2.5	39		Tr	5	Tr
Emersol 132 NF Lily® Stearic Acid[2,3,4]	54.5-55.5	0.5 max.	93/99	205-210	2.5	0.5	50	1.5	45.5				
Emersol 143 Palmitic Acid	58-61	1 max.	93/99	215-223	Tr	0.5	91	4.5	4				
Emersol 150 Stearic Acid[5]	63.9-65.0	1 max.	93/99	197-202	2	1	11	2	83			1	
Emersol 152 NF Stearic Acid[3]	66.5-69.0	1 max.	80/97	196-199			7		90	3			
Emersol 153 NF Stearic Acid[3]	67-69	1 max.	80/97	196-199			5		95				
Emery 400 Stearic Acid	52 min.	9.5 max.	1/40	197-212									
Emery 404 Stearic Acid	53.5-54.5	6-9	1/50	197-209									
Emery 405 Stearic Acid[6]	57 min.	6 max.	40/86	195-205									
Emery 410 Stearic Acid	56.1-60.0	7 max.	40/86	195-209	3	0.5	25	2	63		2.5	4	
Emery 420 Stearic Acid	57.2-63.0	1 max.	85/98	200-207	4	0.5	29	1.5	65		Tr	Tr	
Emery 422 Stearic Acid	55.8-60.0	1 max.	90/99	203-209	3	Tr	41	1	55				

[1]Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.
[2]Corresponding food grade products available.
[3]For external use only, USP XXI/NF XVI.
[4]Powdered grade also available.
[5]80% minimum stearic content.
[6]Tentative specification.

(continued)

Table 13.17: (continued)

Tallow and Modified Fatty Acids

	Specifications				Typical Composition[1]								
					Saturated Acids					Unsaturated Acids			
	Titer, °C	Iodine Value	Color % Trans. 440/550 nm., min.	Acid Value	Myristic $C_{14}H_{28}O_2$	Pentadecanoic $C_{15}H_{30}O_2$	Palmitic $C_{16}H_{32}O_2$	Margaric $C_{17}H_{34}O_2$	Stearic $C_{18}H_{36}O_2$	Palmitoleic $C_{16}H_{30}O_2$	Oleic $C_{18}H_{34}O_2$	Linoleic $C_{18}H_{32}O_2$	Linolenic $C_{18}H_{30}O_2$
Emery® 531 Tallow Fatty Acid	36-44	45-70	19/81	200-208	2.5	0.5	27	1	17	4	42	5	1
Emery 401 Fatty Acid	44-53	34-44	80/95	199-208									
Emery 876 Fatty Acid	35-45	2-6	—	235-269									
Emery 877 Fatty Acid	34-45	2 max.	47/93[2]	240-270	80% Monobasic acids, 20% dibasic acids								
Emery 878 Fatty Acid	—	1 max.	70/95	295-315									

[1]*Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.*
[2]*Not a specification.*

Tallow/Coconut Fatty Acid Blends

	Specifications			
	Acid Value	Iodine Value	Titer, °C	Color % Trans. 440/550 nm., min.
Emery® 515 Fatty Acid	212-218	44-54	35-40	72/96
Emery 516 Fatty Acid	214-216	35-42	38-45	70/94
Emery 517 Fatty Acid	216-222	42 max.	37-40.5	78/94

Linoleic and Vegetable Fatty Acids

	Specifications					Typical Composition[1]										
			Color			Saturated Acids						Unsaturated Acids				
	Titer °C	Iodine Value	% Trans. 440/550 nm., min.	Gardner 1963, max.	Acid Value	Lauric $C_{12}H_{24}O_2$	Myristic $C_{14}H_{28}O_2$	Pentadecanoic $C_{15}H_{30}O_2$	Palmitic $C_{16}H_{32}O_2$	Margaric $C_{17}H_{34}O_2$	Stearic $C_{18}H_{36}O_2$	Myristoleic $C_{14}H_{26}O_2$	Palmitoleic $C_{16}H_{30}O_2$	Oleic $C_{18}H_{34}O_2$	Linoleic $C_{18}H_{32}O_2$	Linolenic $C_{18}H_{30}O_2$
Emersol® 315 Linoleic Acid	5 max.	145-160	72/96	3	195-202		0.5	Tr	3.5	Tr	0.5	Tr	Tr	19.5	65.5	10.5
Emery® 610 Soya Fatty Acid	15-25	125-138	60/90	3	195-205	Tr	0.5		16	Tr	4		1	25.5	48	5
Emery 818 Soya Fatty Acid	15-23	138-145	72/96	3	197-203				11		4		1	27	50	7

[1]*Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.*

Table 13.18: INDUSTRENE and HYSTRENE Fatty and Dibasic Acids *(26)*

Caprylic/Capric Acids

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	% TRANS 440/550 nm, MIN	COLOR LOVIBOND MAX	TYPICAL CARBON CHAIN COMPOSITION: SATURATED C8	C10	C12	C14	C16	C18	UNSATURATED C18:1	OTHERS
Industrene 365*	Caprylic/Capric (Mixture Caprylic/Capric Acid) **67762-36-1**	6 Max	1 Max	355-369	1	70/92	5.0Y-0.5R	60	38					2	

* Available only in bulk
Typical moisture levels are below 0.3%.

Lauric and Myristic Acids

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	% TRANS 440/550 nm, MIN	COLOR LOVIBOND MAX	TYPICAL CARBON CHAIN COMPOSITION: SATURATED C8	C10	C12	C14	C16	C18	UNSATURATED C18:1	OTHERS
Industrene 325	Distilled Coconut (Coconut Acid) **61788-47-4**	22-27	5-10	265-277	0.5	65/90	8.0Y-0.8R	7	6	50	19	9	2	6	1
Industrene 223	Hydrogenated Coconut (Hydrogenated Coconut Acid) **67701-05-7**	23-26	3 Max	266-274	0.3	85/96	2.0Y-0.2R	7	6	51	18	9	2	5	2
Industrene 328	Stripped Coconut (Coconut Acid) **61788-47-4**	27-30	5-10	252-260	0.5	80/96	3.0Y-0.3R			55	24	12	1	4	4
Hystrene 5012	Hydrogenated Stripped Coconut (Hydrogenated Coconut Acid) **143-07-7**	26-33	1 Max	250-260	0.5	85/96	2.0Y-0.2R	1	1	55	23	12	8		
Hystrene 9512	95% Lauric (Lauric Acid) **143-07-7**	41-44	0.5 Max	275-281	0.25	85/96	2.0Y-0.2R		1	96	3				
Hystrene 9912	99% Lauric (Lauric Acid) **143-07-7**	43-45	0.2 Max	276-281	0.25	92/98	1.0Y-0.1R			99					1
Hystrene 9014	90% Myristic (Myristic Acid) **544-63-8**	50-54	0.5 Max	238-245	0.3	85/96	2.0Y-0.2R			2	92	4			2
Hystrene 9514	95% Myristic (Myristic Acid) **544-63-8**	52-54	0.5 Max	241-247	0.3	92/98	1.0Y-0.1R			1	97	1			1

Typical moisture levels are below 0.3%.

(continued)

Table 13.18: (continued)

Stearic and Palmitic Acids		Specifications						Typical Carbon Chain Composition				
								Saturated			Unsaturated	Others
Product	Acid Description (CTFA Adopted Name) CAS Number	Titer °C	Iodine Value	Acid Value	% Unsap Max	% Trans 440/550 nm, Min	Color Max	C14	C16	C18	C18:1	
Hystrene 9016	90% Palmitic (Palmitic Acid) **57-10-3**	59–62	0.5 Max	214–219	0.2	92/98	1.0Y–0.1R Lovibond	1	92	6		1
Industrene 5016	Double Pressed Grade (Stearic Acid) **57-11-4**	53–56	4–7	207–210	0.5	88/96	1.5Y–0.2R Lovibond	3	46	42	5	4
Hystrene 5016 NF-EXT	Triple Pressed Grade (Stearic Acid) **57-11-4**	54.5–56.5	0.5 Max	206–210	0.2	92/98	1.0Y–0.1R Lovibond	2	51	45		2
Hystrene 5016 NF-EXT-VEG	Triple Pressed Grade (Stearic Acid) **57-11-4**	55–57	0.7 Max	205–210	0.2	88/96	1.5Y–0.2R Lovibond	1	52	46		1
Industrene 4516	45% Palmitic (Palmitic Acid) **57-11-4**	54–57	2 Max	204–209	1	88/96	1.5Y–0.2R Lovibond	2	44	52		2
Hystrene 4516	45% Palmitic (Palmitic Acid) **57-11-4**	55–58	0.8 Max	203–209	0.25	92/98	1.0Y–0.1R Lovibond	2	43	52		3
Industrene R	Stearic Acid **57-11-4**	52–64	10 Max	193–213	3		12 Gardner					
Industrene B	Stearic Acid **57-11-4**	57–63	3 Max	198–207	1	40/86	3 Gardner	3	28	65		4
Industrene 7018	70% Stearic (Stearic Acid) **57-11-4**	58–62	1 Max	200–207	0.5	70/92	5.0Y–0.5R Lovibond	3	28	65		4
Hystrene 7018	70% Stearic (Stearic Acid) **57-11-4**	58–62	0.5 Max	200–206	0.3	92/98	1.0Y–0.1R Lovibond	2	28	66		4
Industrene 9018	90% Stearic (Stearic Acid) **57-11-4**	65–68.5	2 Max	195–201	0.5	70/92	5.0Y–0.5R Lovibond		6	91		3
Hystrene 9718 NF-EXT	92% Stearic (Stearic Acid) **57-11-4**	66.5–69	0.8 Max	195–200	0.3	92/98	1.0Y–0.1R Lovibond		4	94		2
Hystrene 9718 NF-EXT-VEG	92% Stearic (Stearic Acid) **57-11-4**	66.5–69	0.8 Max	195–200	0.3	92/98	1.0Y–0.1R Lovibond		5	94		1

Typical moisture levels are below 0.3%.

(continued)

Table 13.18: (continued)

ARACHIDIC AND BEHENIC ACIDS

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	% TRANS 440/550 nm, MIN	COLOR GARDNER MAX	TYPICAL CARBON CHAIN COMPOSITION: SATURATED: C14	C16	C18	C20	C20 & C22	C22	OTHERS
Hystrene 3022	30% Arachidic and Behenic (Hydrogenated Menhaden Acid) **112-85-6**	51-55	4	193-201	1.5	50/90	3	6	30	30		30		4
Hystrene 5522	55% Arachidic and Behenic (Hydrogenated Menhaden Acid) **112-85-6**	60-63	4	178-185	1.5	50/90	3		14	26		55		5
Hystrene 6022	60% Arachidic and Behenic (Behenic Acid) **112-85-6**	68-71	2	169-177	1.5	50/90	3			27	10		60	3
Hystrene 7022	70% Arachidic and Behenic (Behenic Acid) **112-85-6**	63-67	3	170-180	1.5	50/90	3			23		72		5
Hystrene 9022	90% Arachidic and Behenic (Behenic Acid) **112-85-6**	67-72	3	165-175	1.5	50/90	3			6		90		4
Hystrene 9222	92% Behenic (Behenic Acid) **112-85-6**	74-79	2	162-169	2.0		3			2	3		93	2

Typical moisture levels are below 0.3%.

ERUCIC ACIDS

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	COLOR GARDNER MAX	TYPICAL CARBON CHAIN COMPOSITION: SATURATED & UNSATURATED: C18	C20	C22	C24	OTHERS
Hystrene 2290	90% Erucic **112-86-7**	27-37	65-90	160-185	2.0	5	1	3	90	4	2

(continued)

Table 13.18: (continued)

Tallow Type Acids

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	% TRANS 440/550 nm, MIN	COLOR MAX	TYPICAL CARBON CHAIN COMPOSITION: SATURATED C12	C14	C16	C18	UNSATURATED C16:1	C18:1	C18:2	OTHERS
Hystrene 1835	Soap Blend (Mixture Tallow/ Coconut Acid) **67701-05-7**	40 Max	36–42	214–222	1	78/94	4.0Y–0.4R Lovibond	10	6	22	18	3	33	3	5
Industrene 143	Tallow Type **61790-37-2**	39–43	45–65	201–206	1.5		5 Gardner		3	24	17	5	43	5	3
Industrene 145	Tallow Type **61790-37-2**	44–49	36–44	198–207	1.0	80/93			3	26	25	3	39	1	3

Typical moisture levels are below 0.3%.

Oleic Acids

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS: TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	COLOR MAX	TYPICAL CARBON CHAIN COMPOSITION: SATURATED C14	C16	C18	UNSATURATED C16:1	C18:1	C18:2	C18:3	OTHERS
Industrene 105	High-Titer Oleic (Oleic Acid) **112-80-1**	14 Max	85–95	195–204	1.5	6 Gardner	3	6	2	6	70	10		3
Industrene 106	Oleic (Oleic Acid) **112-80-1**	6 Max	95 Max	198–204	1	3 Gardner	2	5	2	6	72	10		3
Industrene 205	Oleic (Oleic Acid) **112-80-1**	14 Max	85–95	195–204	1.5	5.0Y–0.5R Lovibond	2	5	3	5	72	9		4
Industrene 206	Low-Titer Oleic (Oleic Acid) **112-80-1**	6 Max	95 Max	199–204	1	7.0Y–1.2R Lovibond	2	4	1	6	72	9		6
Industrene 210	Canola **67701-08-0**	13 Max	100–125	190–210		10Y–1.5R Lovibond		7	2		63	20	5	3

Typical moisture levels are below 0.3%.

(continued)

Table 13.18: (continued)

Linoleic and Linolenic Acids

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	SPECIFICATIONS TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	% TRANS 440/550 nm, MIN	COLOR GARDNER MAX	TYPICAL CARBON CHAIN COMPOSITION SATURATED C16	C18	UNSATURATED C18:1	C18:2	C18:3	OTHERS
Industrene 120	Linseed (Linolenic Acid) **68424-45-3**	14-18	185-200	197-202	1		5	7	4	20	16	52	1
Industrene 130	Oleic-Linoleic **67701-06-8**	30-38	90-112	198-206	2		4	18	10	31	32	5	4
Industrene 225	Soya (Linoleic Acid) **67701-08-0**	25 Max	135-150	195-201	2	75/85	2	4	5	24	57	8	2
Industrene 226	Soya (Linoleic Acid) **67701-08-0**	26 Max	127-138	195-203	2	70/85	3	11	4	24	53	6	2

Typical moisture levels are below 0.3%.

Food and Kosher Grade Acids

PRODUCT	ACID DESCRIPTION (CTFA ADOPTED NAME) CAS NUMBER	KOSHER	SPECIFICATIONS TITER °C	IODINE VALUE	ACID VALUE	% UNSAP MAX	% TRANS 440/550 nm, MIN	COLOR MAX	TYPICAL CARBON CHAIN COMPOSITION SATURATED C14	C16	C18	UNSATURATED C18:1	C18:2	C18:3	OTHERS
Hystrene 4516 NF-FG	45% Palmitic (Palmitic Acid) **57-11-4**	■	55-59	0.6 Max	203-209	0.25	92/98	1.0Y-0.1R Lovibond	1	44	54				1
Hystrene 5016 NF-FG	Triple Pressed Stearic (Stearic Acid) **57-11-4**		54.5-56.5	0.5 Max	206-210	0.2	92/98	1.0Y-0.1R Lovibond	2	51	45				2
Hystrene 5016 NF-FG-VEG	Triple Pressed Stearic (Stearic Acid) **57-11-4**		55-57	0.5 Max	205-210	0.2	92/98	1.0Y-0.1R Lovibond	1	52	46				1
Hystrene 7018 FG	70% Stearic (Hydrogenated Tallow Acid) **57-11-4**		58-62	0.5 Max	200-205	0.3	92/98	1.0Y-0.1R Lovibond	2	28	66				4
Industrene 8718 FG	87% Stearic (Stearic Acid) **57-11-4**	■	66-68	1 Max	195-200	0.5	92/98	1.0Y-0.1R Lovibond		9	89				2
Hystrene 9718 NF-FG	92% Stearic (Stearic Acid) **57-11-4**		66.5-69	0.5 Max	195-200	0.3	92/98	1.0Y-0.1R Lovibond		4	94				2
Industrene 226 FG	Distilled Soya (Soya Acid) **67701-08-0**	■	26 Max	127-138	195-203	2	70/85	3 Gardner		11	4	24	53	6	2

■ Materials available in Kosher grade.
Typical moisture levels are below 0.3%.

Table 13.19: NEO-FAT Fatty Acids *(59)*

	Product Name	Fatty Acid	SPECIFICATIONS: Titer °C		Iodine Value		Acid Value		Color Lovibond	Moisture	Heat Stability†	Saponification Value		Unsaponifiable	APPROXIMATE CHEMICAL COMPOSITION (GAS CHROMATOGRAPHY): SATURATED: Caproic C-6	Caprylic C-8	Capric C-10	Lauric C-12	Myristic C-14	Pentadecanoic C-15	Palmitic C-16	Margaric C-17	Stearic C-18	Arachidic C-20	UNSATURATED: Myristoleic C-14'	Palmitoleic C-16'	Oleic C-18'	Linoleic C-18''	Linolenic C-18'''
	NEO-FAT*		Min	Max	Min	Max	Min	Max	Max	Max	Max	Min	Max	Max															
SHORT CHAIN SATURATED ACIDS	8	Commercially Pure Caprylic	8.0	12.0		0.7	387	392	1.0 R- 5 Y 5-1/4"	0.2	4.0 R-40 Y	387	394	0.2	5.0	92.0	3.0												
	8-S	98% Min. Commercially Pure Caprylic	15.0			0.5	385	390	0.5 R- 3 Y 5-1/4"	0.2	2.5 R-15Y	385	392	0.2	0.4	99.2	0.4												
	10	Commercially Pure Capric	29.0	32.0		0.5	323	329	0.8 R- 3 Y 5-1/4"	0.2	2.5 R-10 Y	323	331	0.2		1.0	97.0	2.0											
	12	Commercially Pure Lauric	41.5	44.0		0.5	278	282	0.5 R- 3 Y 5-1/4"	0.2	1.5 R-10 Y	278	284	0.2			1.0	97.0	2.0										
	12-43	99% Commercially Pure Lauric	43.0			0.5	278	282	0.5 R- 2 Y 5-1/4"	0.2	1.0 R- 5 Y	278	284	0.2			0.3	99.0	0.7										
	14	Commercially Pure Myristic	52.0			0.5	244	249	0.5 R- 2 Y 5-1/4"	0.2	1.5 R- 8 Y	244	251	0.2				1.5	97.5		1.0								
	255	Stripped Coco	27.5	29.5	8.0	13.0	252	258	1.0 R- 7 Y 5-1/4"	0.3		252	260	0.5			1.0	55.0	22.0		11.0		3.0				6.0	2.0	
	265	Distilled Coco	23.0	26.0		10.0	265	275	1.0 R- 7 Y 5-1/4"	0.3		265	277	0.5		5.0	6.0	52.0	19.0		9.0		2.0				6.0	1.0	
LONG CHAIN SATURATED ACIDS	16	Commercially Pure Palmitic	59.0	61.0		0.5	216	220	0.5 R- 2 Y 5-1/4"	0.2	1.0 R- 6 Y	216	221	0.3					1.0	0.5	92.5	1.0	5.0						
	16-S	97% Commercially Pure Palmitic	61.6			0.5	216	220	0.5 R-2.0 Y 5-1/4"	0.2	1.0 R- 6 Y	216	221	0.3						0.1	98.0	0.2	1.7						
	16-54	Eutectic Palmitic-Stearic	53.0	55.0		0.5	211	213	0.5 R- 2 Y 5-1/4"	0.2	1.5 R- 7 Y	211	214	0.4					2.0	0.5	66.0	1.5	30.0						
	16-56	80% Commercially Pure Palmitic	56.0	58.0		1.0	214	218	0.6 R-3.5 Y 5-1/4"	0.2	2.0 R-12 Y	214	219	0.4					1.5	0.7	80.5	2.0	15.3						
	18	Commercially Pure Stearic	65.5	68.0		1.0	195	200	1.0 R- 5 Y 5-1/4"	0.2	3.5 R-25 Y	197	201	0.5							7.0	2.5	90.0	0.5			trace		
	18-S	Special C. P. Stearic	65.5			0.5	195	200	0.5 R-1.5 Y 5-1/4"	0.2	1.5 R-5.0 Y	197	201	0.5							7.0	2.5	90.0	0.5					
	18-53	Single Pressed Stearic	53.3	54.2	5.0	10.0	207	210	2.0 R- 15 Y 5-1/4"	0.5		207	211	0.8					2.5	0.5	52.0	2.0	38.0				5.0		
	18-54	Double Pressed Stearic	54.0	54.6	4.5	7.0	208	211	0.5 R- 2 Y 5-1/4"	0.5	3.0 R-20 Y xxx	208	212	0.5					2.5	0.5	52.0	2.0	39.0				4.0		
	18-55	Triple Pressed Stearic	55.0	56.0		0.5	208	211	0.5 R- 2 Y 5-1/4"	0.5	1.0 R- 7 Y	208	212	0.5					2.0	0.5	52.0	2.0	43.5						
	18-58	Hydrogenated Tallow Acid	57.0	61.0		1.0	201	206	1.0 R- 5 Y 5-1/4"	0.5	2.5 R-15Y	201	207	0.5					2.0	0.5	29.0	1.5	66.0	1.0					
	18-59	Rubber Grade Stearic	55.0	62.0		9.0	195	208	8.0 R-40 Y 1"	0.5		195	209	2.0				2.0	9.0	0.5	21.0	1.5	60.0	1.0			5.0		
	18-61	Stearic-Palmitic	60.0	64.0		1.0	198	205	1.0 R- 5 Y 5-1/4"	0.5	3.5 R-25 Y	198	206	0.5					4.0	0.5	21.0	1.5	72.0	1.0			trace		
UNSATURATED ACIDS–OLEIC	90-04*	Low Poly-unsaturated Oleic Acid‡		7.0	84.0		200	204	1.0 R- 8 Y 5-1/4"	0.4	xx	200	205	1.0					3.0	0.5	3.0	1.0	trace		1.5	6.5	79.5	4.0	1.0
	92-04*	5°C Max Titer Crystallized White Oleic		5.0		95.0	200	204	1.3 R- 9 Y 5-1/4"	0.4	xx	200	205	1.0					3.0	0.5	3.0	1.0	trace		1.5	6.5	77.0	6.5	1.0
	94-04*	5°C Max Titer Crystallized Red Oil		5.0		95.0	199	204	1.0 R- 7 Y 1"	0.4	xx	199	205	1.5				0.5	3.5	0.5	3.0	1.0	trace		1.5	6.5	76.0	6.5	1.0
	94-10*	8-11°C Titer Crystallized Red Oil	8.0	11.0		95.0	199	204	1.0 R- 7 Y 1"	0.4	xx	199	205	1.5				0.5	3.5	0.5	4.0	1.0	2.0		1.5	6.5	73.0	6.5	1.0
UNSATURATED ACIDS–OTHER	65	Distilled Animal Acid	40.0	44.0	49.0	60.0	201	206	1.5 R- 10 Y 1"	0.5		201	207	1.0					3.0	0.5	29.0	1.0	18.0		1.0	3.5	40.0	3.5	0.5

*Ester Number 1 Maximum
xxxPeroxide Index Max 1
xxFlash Point Min 300°F
†2 Hours at 200°C; 5¼" Lovibond Cell.
‡Polyunsaturates Max 5%

(continued)

Table 13.19: (continued)

PROPERTIES OF FATTY ACIDS—SATURATED, UNSATURATED, AND SUBSTITUTED

	Systematic name	Number of C atoms	Viscosity centipoises (T°C)	Index of refraction (T C)
Saturated				
Capric	Decanoic	10	2.88 (70)	1.4130 (80)
Undecylic	Undecanoic	11	7.30 (50)	1.4164 (80)
Lauric	Dodecanoic	12	4.43 (70)	1.4191 (80)
Myristic	Tetradecanoic	14	5.83 (70)	1.4236 (80)
Pentadecylic	Pentadecanoic	15		1.4254 (80)
Palmitic	Hexadecanoic	16	7.8 (70)	1.4272 (80)
Margaric	Heptadecanoic	17		1.4287 (80)
Stearic	Octadecanoic	18	9.87 (70)	1.4299 (80)
Arachidic	Eicosanoic	20		1.4250 (100)
Behenic	Docosanoic	22		1.4270 (100)
Unsaturated				
Palmitoleic	9-Hexadecenoic	16		1.44103 (70)
Oleic	9-Octadecenoic	18	9.41 (60)	1.4582 (20)
Erucic	13-Docosenoic	22		1.4758 (20)
Linoleic	9,12-Octadecadienoic	18		1.4699 (20)
Linolenic	9,12,15-Octadecatrienoic	18		1.480 (20)
Eleostearic	9,11,13-Octadecatrienoic	18		1.5112 (50)
Substituted				
Ricinoleic	12-Hydroxy-9-octadecenoic	18		1.4716 (20)
Vernolic	12-Epoxy-9-octadecenoic	18		1.4628 (40)

UNSATURATED FATTY ACIDS ($C_nH_{2n-2x}O_2$ where x is an integer from 1 to 5)

Common Name	Geneva Nomenclature	Chemical Formula	Acid Value	Melting Point °C	Iodine Value	Molecular Weight
ONE DOUBLE BOND						
Myristoleic	9-Tetradecenoic	$CH_3(CH_2)_3CH{=}CH(CH_2)_7COOH$	247.87	−4.0	112	226.35
Palmitoleic	9-Hexadecenoic	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	220.53	0.5	100	254.40
Oleic	cis-9-Octadecenoic	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	198.63	13.4	90	282.45
Elaidic	trans-9-Octadecenoic	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	198.63	46.5	90	282.45
Erucic	cis-13-Docosenoic	$CH_3(CH_2)_7CH{=}CH(CH_2)_{11}COOH$	165.72	34.7	75	338.57
TWO DOUBLE BONDS						
Linoleic	9, 12-Octadecadienoic	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	200.06	−5.0	181	280.44
THREE DOUBLE BONDS						
Linolenic	9, 12, 15-Octadecatrienoic	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	201.51	−10.5	273	278.42
αEleostearic	9, 11, 13-Octadecatrienoic	$CH_3(CH_2)_3CH{=}CHCH{=}CHCH{=}CH(CH_2)_7COOH$	201.51	49.0	273	278.42

SATURATED FATTY ACIDS ($C_nH_{2n}O_2$)

Common Name	Geneva Nomenclature	Chemical Formula	Molecular Weight	Acid Value	Melting Point °C
Acetic	n-Ethanoic	CH_3COOH	60.05	934.26	16.6
Butyric	n-Butanoic	C_3H_7COOH	88.10	636.79	−7.9
Caproic	n-Hexanoic	$C_5H_{11}COOH$	116.15	483.00	−3.4
Caprylic	n-Octanoic	$C_7H_{15}COOH$	144.21	389.05	16.7
Capric	n-Decanoic	$C_9H_{19}COOH$	172.26	325.69	31.6
Lauric	n-Dodecanoic	$C_{11}H_{23}COOH$	200.31	280.08	44.2
Myristic	n-Tetradecanoic	$C_{13}H_{27}COOH$	228.36	245.68	53.9
Palmitic	n-Hexadecanoic	$C_{15}H_{31}COOH$	256.42	218.80	63.1
Stearic	n-Octadecanoic	$C_{17}H_{35}COOH$	284.47	197.23	69.6
Arachidic	n-Eicosanoic	$C_{19}H_{39}COOH$	312.52	179.52	75.3
Behenic	n-Docosanoic	$C_{21}H_{43}COOH$	340.57	164.73	79.9
Lignoceric	n-Tetracosanoic	$C_{23}H_{47}COOH$	368.62	152.20	84.2

Table 13.20: Proctor & Gamble Fatty Acids *(39)*

Fatty Acids

Chemical Properties	Whole-Cut Coconut Type C-101	C-103	C-108	C-109	C-110	Whole-Cut Tallow Type T-11	T-18	T-22	Soya S-210	Sunflower S-205	Canola R-910	Tallow/Coco TC-1010T
Acid Value	267-273 (271)	267-273 (271)	266-274 (271)	266-274 (271)	266-274 (271)	200-208 (203)	200-208 (204)	200-210 (205)	197-203 (201)	200 appx.	194-202	214-218 (217)
Iodine Value	1.3 max. (1.1)	5.0 max. (3.2)	5.0 max. (3.2)	5.0-7.0	12 max. (6)	35-42 (42)	40-55 (50)	45-70 (60)	133 min. (136)	140 appx.	105-125	36-41 (39)
Moisture (% KF)	0.3 max. (0.1)	0.3 max. (0.1)	0.3 max. (0.04)	0.2 max.	0.3 max. (0.05)	0.3 max. (0.05)	0.3 max. (0.05)	0.5 max. (0.1)	0.15 max. (0.04)	0.1 max.	0.3 max.	0.3 max. (0.04)
Physical Properties												
Color, Gardner (1963)	(<1)	(<1)	(<1)	(<1)	3 max. (2)		5 max. (2)	7 max. (4)	2 max. (1.5)	3 max.	3 max.	
Color, % Transmittance @ 440nm/550nm	85/95 min. (91/97)	85/95 min. (91/97)	85/95 min. (91/97)	80/95 min.	(80/96)	80/93 min. (85/97)						76/93 min. (94/98)
Average Molecular Weight	(207)	(207)	(207)	(208)	(207)	(276)	(275)	(274)	(280)	(280)	(282)	(260)
Titer (C)	(27)	(25)	(25)	(25)	(25)	44-47 (45)	(42)	37-44 (39)	21-25 (23)		12 max.	38-42 (40)
Approximate Composition (GC)												
C6 Caproic	<1	<1	1	1	1							
C8 Caprylic	6	6	7	7	7							1
C10 Capric	6	6	6	6	6							1
C12 Lauric	50	50	49	49	49	1	1	1	0.5			10
C14 Myristic	19	19	18	18	18	3	3	2	0.5			6
C16 Palmitic	8	8	8	8	8	26	25	22	11	8	5	23
C16=1 Palmitoleic						2	3	3				3
C17 Margaric						2	2	2			0.3	1
C18 Stearic	9	6	6	5	4	25	19	18	4	3	2	17
C18=1 Oleic	1	4	4	5.0-7.0	5	40	42	43	24	20	56	35
C18=2 Linoleic					2	1	4	8	52	67	23	3
C18=3 Linolenic							1	1	8	2.0 max.	11	
C20 Arachidic									0.3	0.5	0.5	
CAS No.	67701-05-7	67701-05-7	67701-05-7	67701-05-7	67701-05-7	67701-06-8	67701-06-8	67701-06-8	67701-08-0	67701-08-0	67701-08-0	67701-06-8

Light Cut Fatty Acid and Methyl Ester

Chemical Properties	C-810	C-810L*	CE-810	Fractionated C-895	C-898	C-899*	C-1095	CE1095
Saponification Value	370 max (365)	366 max		395 max (386)	395 max	386-390	331 max (324)	295-305 (302)
Add Value	358-368 (364)	345-365 (357)	0.5 max (0.2)	380-394 (386)	380-394	385-389	320-330 (324)	0.5 max (0.3)
Iodine Value	0.5 max (0.2)	0.5 max (0.2)	0.5 max (0.2)	0.2 max (0.1)	0.2 max	0.2 max	0.5 max (0.3)	0.6 max (0.3)
Moisture, (%, KF)	0.2 max (0.04)	0.2 max (0.06)	0.15 max (0.06)	0.2 max (0.03)	0.2 max	0.2 max	0.2 max (0.03)	0.15 max (0.04)

(continued)

Table 13.20: (continued)

Physical Properties

Color - Lov.5¹/₄" Yellow/Red	3/0.8 max (1.1/0.1)	3/1.0 max (1.0/0.0)		3/0.8 max (1.2/0.2)	3/0.8 max	10/1 max	3/0.8 max (1.4/0.3)	
Color-% Transmittance @ 460nm/550nm			95 min (99)					95 min (98)
Avg. Molecular Weight	(154)	(157)		(145)		(144)	(173)	
Titer, (C)	(3)	(3)		(14)		(14)	(30)	
Specific Gravity 25/25 C			0.870					(0.874)
Melting Point (C)			-29					-14

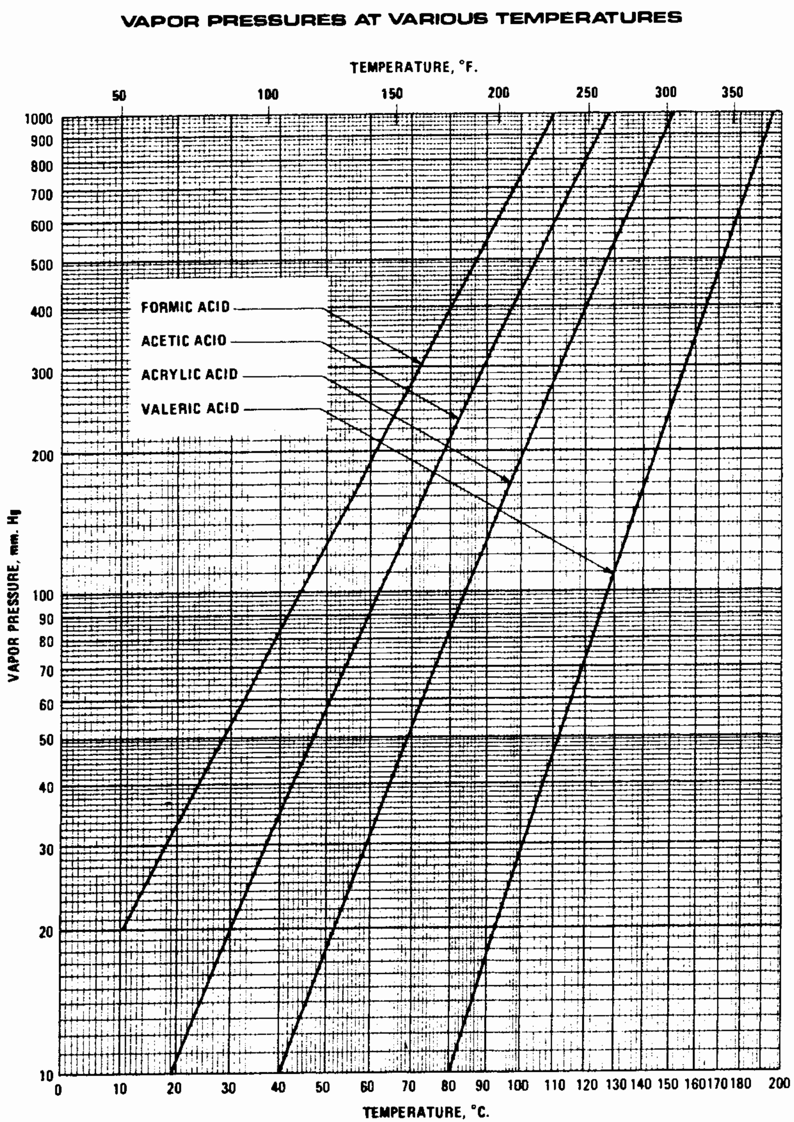
Approximate Composition

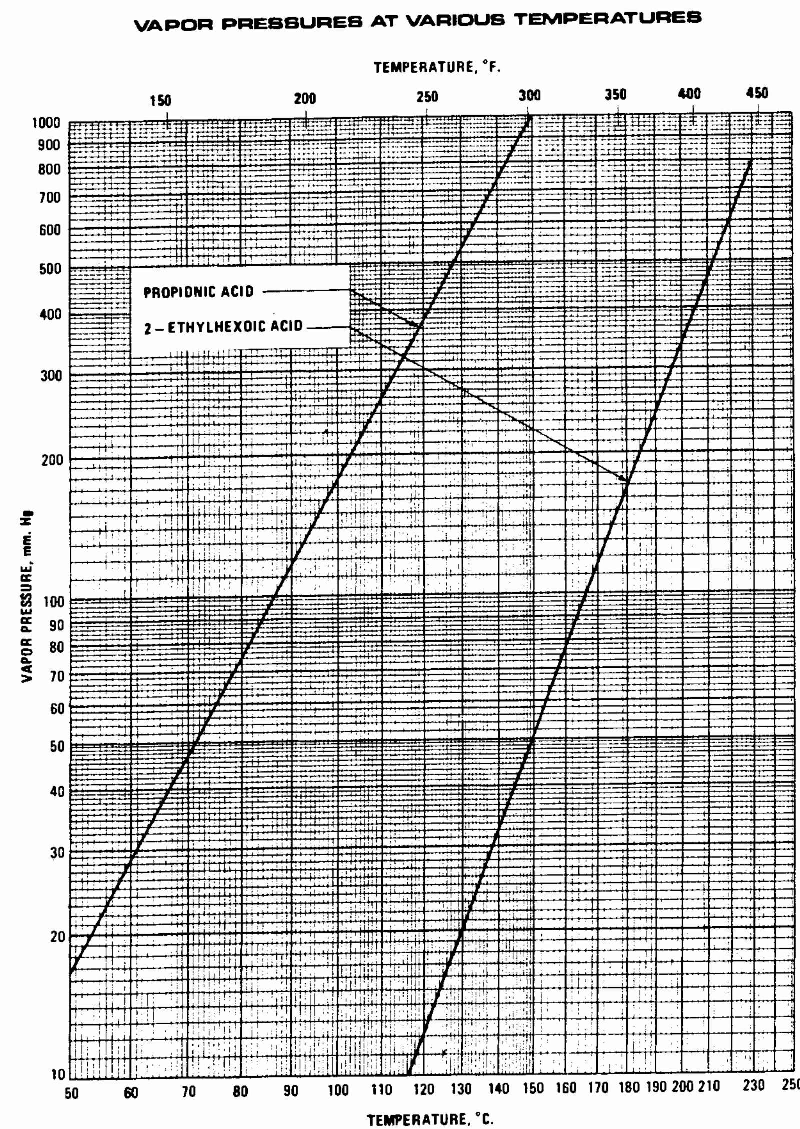
C6 Caproic	6 max (4)	0.50 max (0.2)	6.0 max (4)	2.0 max (0.4)	1.0 max	0.6 max		
C8 Caprylic	53-60 (55)	53-63 (57)	51-58 (55.9)	95.0 min (97.5)	98.0 min	99.0 min	(0.9)	(0.4)
C10 Capric	34-42 (39)	37-47 (41)	34-42 (39.3)	(1.5)	1.0 max	0.6 max	95.0 min (96.9)	95.0 min (96.6)
C12 Lauric	2 max (0.4)	1.5 max (0.6)	1.0 max (0.5)	0.5 max (0.0)		0.1 max	(1.4)	(1.7)
C14 Myristic								(0.2)
CAS No.	67762-36-1	67762-36-1	67762-39-4	124-07-02	124-07-02	124-07-02	334-48-5	110-42-9

Table 13.21: Union Carbide Acids *(19)*

	2-Ethylhexoic Acid $C_4H_9CH(C_2H_5)COCH$	Isopentanoic Acid C_4H_9COOH	Propionic Acid C_2H_5COOH	Valeric Acid C_4H_9COOH
Molecular Weight	144.21	102.13	74.08	102.13
Pounds per gallon @20°C	7.56	7.76	8.28	6.9
Specific Gravity @ 20°/20°C	0.09077	0.9323	0.9952	0.9406
Boiling Point @ 760 mmHg, °C	227.0	175.0	140.8	185.5
Vapor Pressure @ 20°C, mmHg	>0.1	0.21	2.4	0.1
Percent Solubility @ 20°C				
In Water	0.1	—	Complete	2.4
Water In	1.4	—	Complete	13.0
CAS Registration Number	149-57-5	503-74-2	79-09-4	109-52-4

Table 13.21: (continued)





Amines

ALKYL AMINES

Table 14.1: Monomethylamine *(2)*

CH_3NH_2

Monomethylamine is a colorless, flammable gas with a strong ammoniacal odor; it is sold commercially as a 30% by weight aqueous solution. It is soluble in ethyl alcohol, ethyl ether, and many other organic substances, as well as in water. It is used in the tanning industry, in the manufacture of dyestuffs, in many synthetic products, and in the treatment of cellulose acetate rayon for dyeing.

Typical Properties and Specifications

Boiling point (75 mm.)	-6°C.
Flash point (30% solution)	0.3°C.
Melting point	-92.5°C.
Specific gravity at -10.8°/15°C.	0.699
Solubility in water	Very soluble
Weight per gallon (30% solution) at 68°F.	7.7 lbs.
Ammonia	Less than 0.2% by weight of solution
Concentration	3 to 3.5% by weight in water gas
Formaldehyde	Less than 0.3% by weight of solution
Purity	Not less than 98 mol % of total amines

Table 14.2: Dimethylamine *(2)*

$(CH_3)_2NH$

Dimethylamine is a colorless gas with a strong ammoniacal odor. The commercial product is an aqueous solution containing 25% by weight of dimethylamine. It is soluble in ethyl alcohol, ethyl ether, water, and many organic solvents. It is used as a dehairing agent in the tanning industry, in the manufacture of antioxidants, dyes, flotation agents, gasoline stabilizers, pharmaceuticals, rubber accelerators, emulsifiers, and cleaning compounds.

(continued)

Table 14.2: (continued)

Typical Properties and Specifications

Boiling point (764 mm.)	7.2 to 7.3°C.
Description	Gas at ordinary temperature
Flash point (25% solution)	Approx. 6.25°C.
Melting point	-96°C.
Specific gravity at -6°C.	0.6865
Solubility in water	Soluble
Weight per gallon (25% solution, 68°F.)	Approx. 7.8 lbs.
Ammonia	Not more than 1% by wt. of sol.
Concentration	25 to 25.5% by wt. in water
Formaldehyde	Not more than 0.5% by wt. of sol.
Purity	Not less than 98 mol % of total amines

Table 14.3: Trimethylamine *(2)*

$(CH_3)_3N$

Trimethylamine is a colorless, flammable, easily condensible gas with a pungent, ammoniacal odor. The commercial product is an aqueous solution containing 25% by weight of trimethylamine. It is very soluble in water and is used as a warning agent in bottled gas, as an insect attractant, and in organic synthesis.

Typical Properties and Specifications

Boiling point	Approx. 3.5°C.
Critical temperature	161°C.
Critical pressure	41 atm.
Decomposition temperature	800 to 1300°C.
Dielectric constant at 4°C.	2.9
Electrical conductivity	2.2×10^{-12} reciprical ohms at -33.5°C.
Heat of combustion	578.6 kg. cal. per mol
Ionization constant at 25°C.	6.5×10^{-5} for solutions 0.001 N to 0.06N
Heat of evaporization at BP	95.6 cal. per g.
Melting point	-124°C.
Specific gravity at -5°C.	0.662
Surface tension at -4°C.	17.4 dynes per cm.
Solubility in water at 19°C.	1 liter of aqueous saturated solution contains 410 g. of amine
Absolute viscosity at -33.5°C.	3.208 millipoises
Ammonia	Not more than 0.2% by wt. of solution
Formaldehyde	Not more than 0.3% by wt. of solution
Purity	Not less than 98 mol %

Table 14.4: Freezing Points of Aqueous Methylamine Solutions *(34)*

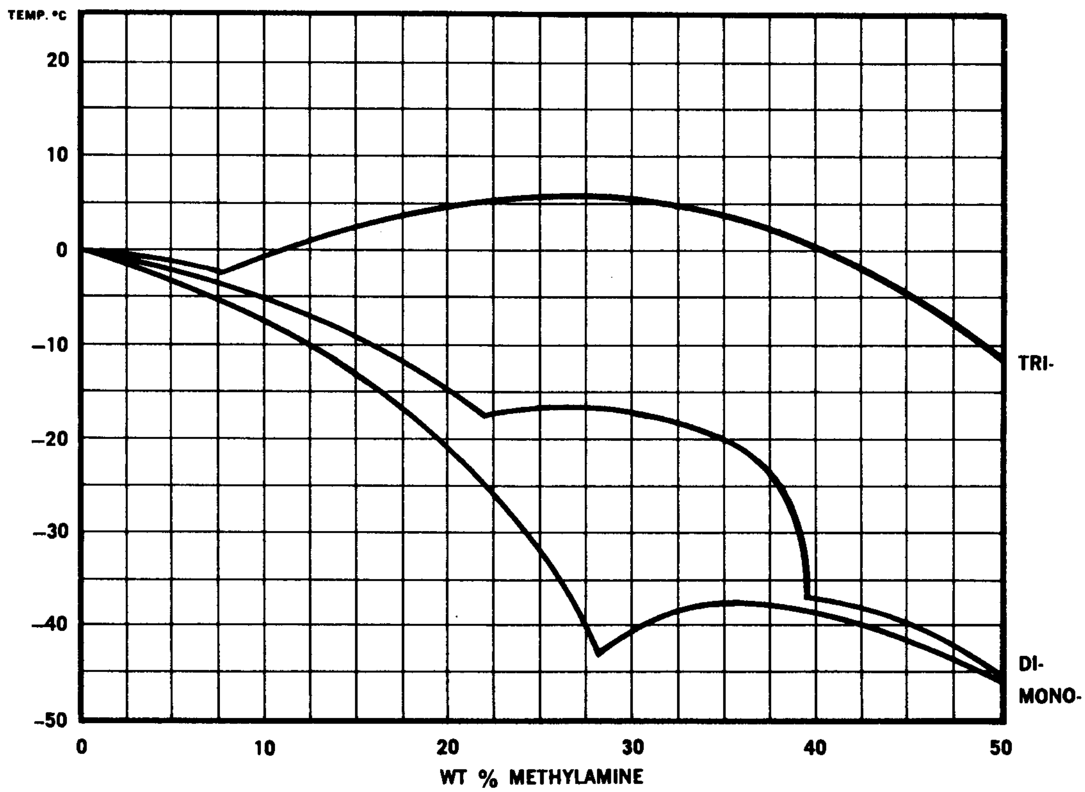


Table 14.5: Binary Azeotropes of Methylamines *(34)*

	Azeotrope b.p., °C		Wt. % A
A = Monomethylamine			
B – Component as follows:			
Trimethylamine at 760 mm	– 6.5		70
60 psig	36		85
210 psig	75		90-92
1-3 Butadiene	– 9.5		41.4
1-Butene	–13		22.2
cis-2-Butene	– 9.6		47.5
trans-2-Butene	–10.4		48.5
1-Butene-3-yne	– 6.8		97.5
Isoprene		Minimum B.P.	
2-Methylpropane	–19.9		25.5
2-Methylpropene	–14.3		32
Butane	–14.0		37.6
Amylenes		Minimum B.P.	
A = Dimethylamine			
B – Component as follows:			
Trimethylamine at 760 mm	3		26
107 psig	73		72
Ammonia		Non-azeotrope	
3-Methyl-1-Butene		Non-azeotrope	
A = Trimethylamine			
B – Component as follows:			
Dimethyl ether		Non-azeotrope	
1-Butene		Non-azeotrope	
2-Methylpropene		Non-azeotrope	
n-Butane		Non-azeotrope	
2-Methylpropane		Non-azeotrope	
Acetic acid	149		20
Ammonia	–34		27
Boron trifluoride	230		47
Formic acid	179		75

Table 14.6: Solubility Data for Methylamines *(34)*

solubility of some inorganic salts in methylamines

SALT	MONO-	DI-	TRI-
AgI	v	v	A i
$AgNO_3$	v	v	—
Ag_2SO_3	s	—	—
Ag_2SO_4	A i	—	—
$BaBr_2$	—	s	—
BaI_2	A v	A v	A s
$Ba(NO_3)_2$	s	s	s
$Ba(SCN)_2$	v	m	i
$BiBr_3$	—	v	—
$BiCl_3$	A m	—	—
BiI_3	A v	v	s
Bi_2S_3	s	—	—
Br_2[a]	v	R v	—
CaC_2	i	—	—
CaI_2	—	v	—
$Ca(NO_3)_2$	m	i	i
$CdBr_2$	—	A m	—
$Cd(CN)_2$	—	m	—
CdI_2	—	v	m
$Cr_2(SO_4)_3$	i	—	—
CuCl	R	—	—
$CuHAsO_3$	s	—	—
CuS	s	—	i
CuSCN	v	—	—
$CuSO_4$	i	—	—
FeI_2	—	m	—
$Fe_2(SO_4)_3$	A i	—	—
$Hg(CN)_2$	v	v	—
HgI_2	v	v	m
$Hg(SCN)_2$	s	—	s
I_2[b]	v	v	s
$KAg(CN)_2$	—	s	—
KCN	—	s	—
KI	—	s	i
KNO_3	s	—	—
K_2PtCl_4	—	s	—
K_2PtCl_6	s	—	—
KSCN	v	—	—
LiCl	v	m	—
$Mg(NO_3)_2$	—	A s	—
NaBr	—	s	—
$NaClO_3$	m	s	—
$NaNO_3$	v	s	s
$NiSO_4$	i	—	—
P (red)	s	—	i
P (yellow)[c]	m	—	—
$PbBr_2$	—	m	—
PbI_2[d]	A s	A s	A s
$Pb(SCN)_2$	A v	—	m
PtI_2	—	s	—
S	v	—	s
SbI_3	—	v	i
SnI_4	A i	m	—
SrI_2	—	A v	—
$Sr(NO_3)_2$	v	—	—
$TlNO_3$	v	m	s
$UrO_2(C_2H_3O_2)_2$[e]	s	—	—
$UrO_2(NO_3)_2$	—	—	i
ZnS	i	—	—

LEGEND: v = very soluble; m = moderately soluble; s = slightly soluble; i = insoluble; A = formation of an aminate; R = marked reaction

a) Bromine reacts with dimethylamine with the evolution of heat to form a very soluble crystalline compound. With methylamine, the reaction is much more violent and a black residue is formed in addition to a soluble crystalline product.

b) Iodine is extremely soluble in mono- and dimethylamine, but not in trimethylamine. On standing, the deep color of the solution fades in color. Iodine is only slightly soluble in trimethylamine but, after some weeks, colorless crystals separate from this solution.

c) Yellow phosphorus is soluble in monomethylamine, forming almost colorless solutions, but on standing the red form, which is only slightly soluble, separates.

d) PbI_2 turns white on contact with the amines. By heating the tubes very gently, the original yellow color returns, indicating that the amine of crystallization has been removed. On cooling, the PbI_2 again turns white.

e) A solution of $UrO_2(C_2H_3O_2)_2$ gelatinizes on standing for some days.

solubility of methylamines in organic liquids

Volumes of gas per 1 cc of liquid Pressure = 1 atmosphere; temperature = 20°C

SOLVENT	MONO-	DI-	TRI-
Aniline	271 cc	520 cc	300 cc
Anisole	89	252	185
Benzyl alcohol	314	528	322
i-Butanol	298	598	405
n-Butanol	303	504	379
Cedrene	34	106	86
α-Chloronaphthalene	52	174	130
Cymene	48	182	177
Decahydronaphthalene	24	116	156
Diacetone alcohol	420	457	345
Dibenzylether	115	154	120
o-Dichlorobenzene	64	252	240
Diethanolamine	313	497	74
Diethylaniline	60	180	134
Diethylene glycol mono-ethyl ether	336	588	216
Dimethylaniline	64	230	149
Dimethylcyclohexylamine	67	187	187
Dimethylformamide	132	298	78
Ethanol	440	727	600
Ethylene glycol	630	860	369
Furfuryl alcohol	413	679	410
Methanol	654	992	573
Methylcyclohexanol	219	439	256
Monoethanolamine	216	379	48
Monoethylaniline	113	324	228
Monomethylaniline	197	406	223
Morpholine	255	580	138
Nitrobenzene	88	226	154
o-Nitrotoluene	86	221	149
Pinene	34	156	176
n-Propanol	339	600	439
Quinoline	92	212	255
Tetrahydronaphthalene	40	170	151
o-Toluidine	88	430	242
Triethylene glycol	316	488	164
Trimethylene glycol	480	722	307

Table 14.7: Monoethylamine *(2)*

$C_2H_5NH_2$

Monoethylamine is a water-white liquid which is commercially available as a 70% aqueous solution. It is soluble in ethyl alcohol, methyl alcohol, the paraffin hydrocarbons, aromatic and aliphatic hydrocarbons, ethyl ether, ethyl acetate, acetone, fixed oils, mineral oil, oleic and stearic acids. It is also soluble in hot paraffin and carnauba waxes, which solidify when cooled.

Typical Properties and Specifications

(Anhydrous grade)	
Distillation range	15-18°C
Flash point (open cup)	Below 20°F
Purity	97-99%
Specific gravity at 15/15°C	0.689
Weight per gallon	5.70 lbs
(70% Solution)	
Boiling point	16.6°C
Color	Water-white
Critical temperature	183.2°C
Dissociation constant at 25°C.	5.6 x 10^{-4}
Heat of combustion	Gas 9157 cal./g. Liquid 9058 cal./g.
Heat of vaporization at 15°C	14.57 cal./g.
Heat of solution in water at 19°C	6330 cal. per mol of solute at infinite dilution
Melting point	−80.6°C
Purity	At least 70%
Specific gravity at 20°/20°C	0.79-0.80
Weight per gallon (20°C)	6.63 lbs.

Table 14.8: Diethylamine *(2)*

$(C_2H_5)_2NH$

Diethylamine is a water-white liquid with an ammoniacal odor. It is soluble in water, ethyl alcohol, paraffin hydrocarbons, aromatic and aliphatic hydrocarbons, ethyl ether, ethyl acetate, acetone, fixed oils, mineral oil, oleic and stearic acids. It dissolves hot paraffin and carnauba waxes, which solidify when cooled. It is used as a selective solvent for the removal of impurities from oils, fats, ond waxes where its property of hydrating in aqueous solution is utilized; also used in the manufacture of rubber chemicals, textile emulsions, dyes, flotation agents, resins, polymerization inhibitors, gum inhibitors, drugs, and insecticides.

Typical Properties and Specifications

Boiling point	56.0°C
Critical density	0.246 g./cc.
Critical pressure	36.2 atm
Critical temperature	223.5°C
Dissociation constant	1.26 x 10^{-3}
Flash point (open cup)	Below 0°F
Heat of combustion	
Gas	9995 cal./g.
Liquid	9882 cal./g.
Heat of Vaporization at 58°C	91.03 cal./g.
Heat of solution in water at room temperature	8220 cal./mol of solute at infinite dilution
Melting point	−50.0°C
Specific gravity at 20/20°C	0.71
20/4°C	0.711
Specific heat of liquid at 22.5°C	0.516 cal./g.
Refractive Index at 17.6°C	1.3873
Viscosity at 25°C	0.346 centipoise
Weight per gallon (20°C)	5.89 lbs.
Distillation range	
Initial boiling point	Not below 53°C
Final boiling point	Not above 59.5°
Purity	At least 98%
Water insoluble	None

Table 14.9: Triethylamine *(2)*

$(C_2H_5)_3N$

Triethylamine is a colorless liquid, freely soluble in water at temperatures below 18°C., soluble in ethyl alcohol, methyl olcohol, ethyl ether, ethyl acetate, aliphatic and aromatic hydrocarbons, acetone, fixed oils, mineral oil, oleic and stearic acids, and in hot carnauba and paraffin waxes, the latter two solidifying when cooled. It is used in the manufacture of corrosion inhibitors, emulsifying agents, dyestuffs, and insecticides.

Typical Properties and Specifications

Boiling point	89.5°C
Critical solution temperature (in water)	18°C
Dissociation constant	6.4×10^{-4}
Flash point (open cup)	20°F
Heat of combustion	10,248 cal./g.
Heat of solution in water	10,040 cal./mol of solute at infinite dilution
Melting point	−114.8°C
Specific gravity at 20/20°C	0.730
Refractive index at 20°C	1.4003
Weight per gallon (20°C)	6.1 lbs.
Color	Water-white
Distillation range	
Initial boiling point	Not below 85°C
Final boiling point	Not above 91°C
Purity	98.5%, min.
Water insoluble (20-30°C)	None

Table 14.10: n-Propylamine *(2)*

1-Aminopropane $CH_3CH_2CH_2NH_2$

n-Propylamine is a colorless liquid soluble in water, methyl and ethyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic, aliphatic and paraffin hydrocarbons, fixed oils, mineral oil, oleic and stearic acids, and hot carnauba and paraffin waxes, the latter two solidifying when cooled.

Boiling point (760 mm)	49-50°C
Distillation range	46-51°C
Flash point	Below 20°F
Melting point	−83°C
Purity	95-99% (min.)
Refractive index at 20°C	1.3910
Specific Gravity at 20°C	0.718
Weight per gallon (at 20°C)	5.99 lbs.

Table 14.11: Di-n-Propylamine *(2)*

$(C_2H_5CH_2)_2NH$

Di-n-propylamine is a colorless liquid, soluble in ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, paraffin hydrocorbons, aliphatic and aromatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. It dissolves hot paraffin and carnauba waxes which solidify when cooled. It is partly soluble in water.

Boiling point	110-1°C
Flash point	45°F
Melting point	−39.6°C
Purity	97% min.
Specific gravity at 20°C	0.74
Refractive index at 20°C	1.4063
Weight per gallon at 20°C	6.18 lbs.

Table 14.12: Mutual Solubility of Di-n-Propylamine and Water at Various Temperatures *(2)*

WEIGHT % AMINE	TEMP., °C.	WEIGHT % AMINE	TEMP., °C.
1.96	52.6	47.54	−1.5
2.42	44.1	60.40	4.2
2.91	36.1	64.06	8.0
5.86	12.2	73.33	17.5
9.33	−0.6	78.69	24.7
12.27	−2.2	82.15	31.2
15.28	−3.5	85.83	39.0
25.21	−4.5*	89.26	49.0
33.69	−4.8	93.25	74.8
44.68	−2.9		

* Upon cooling to −5.0° the first blue opalescence was noted at −4.9°.

Table 14.13: Solubility Curve at 25° for the System Di-n-Propylamine-Water-Ethanol *(29)*

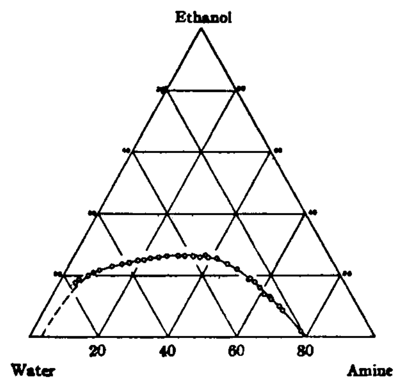


Table 14.14: Isopropylamine *(2)*

2-Aminopropane $CH_3CH(NH_2)CH_3$

This water-white, primary aliphatic amine is available commercially in an anhydrous form. It is soluble in water, methyl and ethyl alcohols, ethyl ether, ethyl acetate, aromatic and aliphatic hydrocarbons, acetone, mineral oil, fixed oils, oleic and stearic acids. It is soluble in hot paraffin and carnauba waxes, which solidify on cooling. It is potentially useful as an intermediate in such manufactured products as dyestuffs, surface-active agents, textile specialties, pharmaceuticals, bactericides, insecticides, and cleaning compounds. It is also used as a dehairing agent in the leather industry.

Boiling point	31.9°C
Flash point	<20°F
Melting point	−101.2°C
Specific gravity at 25/4°C	0.686
Vapor pressure at 15°C	385 mm
pH of 0.1 *N* aqueous solution	11.57
Boiling range	31-35°C
Color	Water-white

Table 14.15: Di-Isopropylamine *(2)*

$[(CH_3)_2CH]_2NH$

Di-isopropylamine is a water-white liquid with an amine odor. It is soluble in methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, mineral oil, fixed oils, oleic and stearic acids, and only partly soluble in water. It dissolves hot paraffin and carnauba waxes which solidify on cooling.

Boiling range	81-85°C
Flash point	20°F
Specific gravity at 20/20°C	0.726

Table 14.16: n-Butylamine *(2)*

1-Aminobutane $CH_3CH_2CH_2CH_2NH_2$

n-Butylamine is a colorless liquid with an ammoniacal odor. It is miscible with water, ethyl alcohol, ethyl ether, paraffin hydrocarbons, and many organic solvents, and dissolves a wide range of materials. The butylamine salts and soaps are usually soluble in hydrocarbons. It behaves in many ways like monoamylamine, but will not produce a constant-boiling mixture with water. This compound is used in the manufacture of specialty soaps, emulsifying agents, desizing agents for textiles, rubber chemicals, flotation agents, corrosion inhibitors, dyestuffs, insecticides, and pharmaceuticals.

Boiling point (760 mm)	77.8°C
Flash point	45°C
Heat of combustion	710 kg. cal. per mol
Melting point	−50.5°C
Specific gravity at 20/20°C	0.7385
Solubility in water	Complete
Solubility of water in solvent	Complete
Refractive index at 20°C	1.4044
Viscosity at 25°C	0.68 centipoise
Vapor pressure at 20°C	0.01 mm
Weight per gallon at 20°C	6.15 lbs.
Acid insoluble	1.0% max.
Distillation range	
Initial boiling point	Not below 73.0°C
Not less than 95%	Below 82.0°C
Final boiling point	Not above 86.0°C
Purity	94% min.

Table 14.17: n-Dibutylamine *(2)*

$(C_4H_9)_2NH$

n-Dibutylamine is a water-white liquid with an ammoniacal odor. It is miscible with a large number and variety of organic solvents but its solubility in water is limited. It is soluble in ethyl and methyl alcohols, ethyl ether, ethyl acetate, acetone, aliphatic, and aromatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. While it dissolves hot paraffin and carnauba waxes, these solidify on cooling. It is used in organic synthesis where its derivatives are used as flotation reagents, dyestuffs, rubber vulcanization accelerators and corrosion inhibitors.

Boiling point	161°C
Flash point (open cup)	135°F
Specific gravity at 20/20°C	0.76
20/4°C	0.767
Refractive index at 20°C	1.4186
Vapor pressure at 20°C	2.5 mm
Weight per gallon at 20°C	6.33 lbs.
Acid insoluble	0.6% max.
Distillation range	
Initial boiling point	Not below 153°C
Not less than 95%	Below 163°C
Final boiling point	Not above 172°C
Purity	98% min.

Table 14.18: n-Tributylamine *(2)*

$(C_4H_9)_3N$

n-Tributylamine is a water-white to light yellow liquid with an ammoniacal odor. It is soluble in ethyl alcohol, methyl alcohol, aliphatic and aromatic hydrocarbons, ethyl acetate, acetone, fixed oils, mineral oil, oleic and stearic acids, hot carnauba and paraffin waxes, the latter two solidifying when cooled, and most organic solvents. It is almost insoluble in water. Its sulfuric acid salts are water-soluble. It is used in the manufacture of corrosion inhibitors, emulsifying agents, dyestuffs, and insecticides.

Boiling point	214°C
Coefficient of expansion per °C	0.00105
Flash point (open cup)	187°F
Melting point	−70°C
Specific gravity at 20/20°C	0.78
20/4°C	0.778
60/15°C	0.755
Refractive index at 20°C	1.431
Surface tension at 20°C	24.9 dynes/cm.
Viscosity at 25°C	1.35 centipoise
at 60°C	0.73 centipoise
Weight per gallon at 20°C	6.5 lbs.
Acid insoluble	0.25% max.
Distillation range	
Initial boiling point	Not below 203°C
Not less than 95%	Below 216°C
Final boiling point	Not above 219°C
Purity	99% min.

Table 14.19: Isobutylamine *(2)*

$(CH_3)_2CHCH_2NH_2$

Isobutylamine is a colorless liquid soluble in water, methyl and ethyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids, and hot paraffin and carnauba waxes, the latter two solidifying when cooled.

Boiling point	68–9°C
Flash point	Below 20°F
Melting point	−85°C
Specific gravity at 20°C	0.731
Refractive index at 20°C	1.3985
Weight per gallon at 20°C	6.10 lbs.
Distillation range	66–69°C
Purity	99% min.

Table 14.20: Diisobutylamine *(2)*

$(C_4H_9)_2NH$

Diisobutylamine is a colorless liquid soluble in ethyl alcohol, methyl alcohol, aromatic and aliphatic hydrocarbons, ethyl ether, ethyl acetate, acetone, fixed oils, mineral oil oleic and stearic acids. It is insoluble in water and while it dissolves hot paraffin and carnauba waxes, these solidify on cooling.

Flash point	85°F
Melting point	−70°C
Specific gravity at 20°C	0.75
Refractive index at 20°C	1.4124
Weight per gallon at 20°C	6.22 lbs.
Distillation range	136–140°C
Purity	97% min.

Table 14.21: sec-Butylamine *(2)*

$$CH_3CHNH_2C_2H_5$$

sec-Butylamine is a water-white liquid with a characteristic amine odor. It is soluble in water, methyl and ethyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, mineral oil, fixed oils, stearic and oleic acids. It dissolves hot paraffin and carnauba waxes but these solidify on cooling.

Boiling point (772 mm)	66°C
Flash point	20°F
Melting point	−104°C
Specific gravity at 20/20°C	0.725
Boiling range	62–69°C

Table 14.22: Mono-n-Butyl Diamylamine *(2)*

$$C_4H_9N(C_5H_{11})_2$$

This amine is a light straw colored liquid with an amine odor. It is soluble in acetone, ethyl ether, ethyl acetate, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, and oleic and stearic acids. It is insoluble in water, methyl alcohol, and although soluble in hot paraffin and carnauba waxes, these solidify on cooling.

Flash point	200°F
Specific gravity at 20/20°C	0.788
Weight per gallon at 20°C	6.56 lbs.
Boiling range	229–241°C

Table 14.23: n-Amylamine *(2)*

$$CH_3(CH_2)_4NH_2$$

n-Amylamine is a colorless liquid with an ammoniacal odor. Commercially it is a mixture of the following isomers, although a pure product is available.

	B.P.°C.
tert-Amylamine	82
sec-Isoamylamine	87
2-Aminopentane	89
3-Aminopentane	90
Active amylamine	94
sec-Amylamine	95
n-Amylamine	104

It is miscible with water, ethyl and methyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, pyridine, oleic and hot stearic acids, hot paraffin and hot carnauba waxes, the latter two solidifying when cooled. It dissolves a varied range of materials which are usually dissolved with difficulty by other organic solvents. It is used as a corrosion inhibitor and as a base for emulsifiers which are soluble in vegetable and mineral oils. It is also employed in textile lubrication, and as a raw material in the manufacture of dyestuffs, emulsifying agents, antioxidants, desizing agents for textiles and pharmaceuticals.

Boiling point	102–104°C	Viscosity at 20°C	0.01018 poise
Coefficient of expansion at 20–60°C	0.00116	Vapor pressure at 26°C	35 mm
Constant-boiling mixture		Weight per gallon at 20°C	6.41 lbs.
n-Amylamine	79–82.5% 82–85°C B.P.	Color	Water-white
Water	21–17.5%	Distillation range	
Flash point (open cup)	65°F	Initial boiling point	Not below 84°C
Heat of vaporization	108 cal./g.	Not less than 95%	Below 100°C
Melting point	−55°C	Final boiling point	Not above 110°C
Specific gravity at 20/20°C	0.76–0.78	Purity	90% min.
Specific heat at 60°F	0.65 cal./g.	Water dilution	20:1 min.
Refractive index at 19°C	1.4068		
Surface tension at 13°C	24.4 dynes/cm.		

Table 14.24: sec-Amylamine (2)

$CH_3CH(NH_2)C_3H_7$

sec-Amylamine is a colorless liquid with an amine odor. It is soluble in water, methyl and ethyl alcohols, aromatic and aliphatic hydrocarbons, ethyl ether, ethyl acetate, acetone, fixed oils, oleic and stearic acids. It dissolves hot paraffin and carnauba waxes which solidify when cooled.

Boiling point (760 mm)	91-92°C
Flash point	20°F
Specific gravity at 20°C	0.739
Refractive index at 20°C	1.4047
Weight per gallon at 20°C	6.15 lbs.
Distillation range	89-92°C
Purity	95-99% min.

Table 14.25: Diamylamine (Mixed Isomers) (2)

$(C_5H_{11})_2NH$

Diamylamine is a colorless to straw-colored liquid with an ammoniacal odor, which is composed of a mixture of amyl isomers. It is soluble in ethyl alcohol, methyl alcohol, ethyl ethers, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. It is insoluble in water and while soluble in hot paraffin and carnauba waxes, these solidify on cooling. It is a solvent for oils, resins, and some cellulose esters. Introduction of the amyl group imparts oil solubility to otherwise oil-insoluble substances. It is used as a corrosion inhibitor, and in chemical synthesis.

Coefficient of expansion at 20-60°C	0.00102
Flash point (open cup)	158°F
Heat of vaporization	83 cal./g.
Specific gravity at 20/20°C	0.77-0.78
Specific heat at 60°F	0.54 cal./g.
Refractive index at 20°C	1.4259
Surface tension at 13°C	24.4 dynes/cm.
Vapor pressure at 26°C	9 mm
Viscosity at 20°C	0.01264 poise
Weight per gallon at 20°C	6.45 lbs.
Acid insoluble	0.5% min.
Distillation range	
Initial boiling point	Not below 175°C
Not less than 95%	Below 202°C
Final boiling point	Not above 218°C
Purity	99% min.
Sulfur	0.06% min.

Table 14.26: Triamylamine (Mixed Isomers) (2)

$(C_5H_{11})_3N$

Triamylamine is a water-white to light yellow, stable liquid which is strongly basic in reaction. It is soluble in ethyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids, and in hot paraffin and carnauba waxes, the latter two solidifying when cooled. It is insoluble in water and methyl alcohol. It is an excellent corrosion inhibitor of steel in a 0.13% solution in normal sulfuric acid. It is used in the manufacture of emulsifying agents, dyestuffs, and insecticides.

Coefficient of expansion	0.00091
Flash point (open cup)	215°F
Heat of vaporization	79 cal./g.
Specific gravity at 20/20°C	0.79-0.80
Specific heat at 60°F	0.51 cal./g.
Refractive index at 18°C	1.4374
Surface tension at 13°C	24.4 dynes/cm.
Viscosity at 20°C	0.02421 poise
Vapor pressure at 26°C	7 mm
Weight per gallon at 20°C	6.60 lbs.
Acid insolubles	1.0% max.
Distillation range	
Initial boiling point	Not below 234°C
Not less than 50%	Above 244°C
Not less than 95%	Below 256°C
Final boiling point	Not above 260°C
Purity	99% min.

Table 14.27: sec-Hexylamine *(2)*

$CH_3CHNH_2C_4H_9$

sec-Hexylamine is a colorless liquid with an amine odor and soluble in water, ethyl alcohol, and paraffin hydrocarbons.

Flash point	55°F
Specific gravity at 20°C	0.746
Weight per gallon	6.22 lbs.
Distillation range	107-110°C
Purity	95-99%

Table 14.28: 2-Ethylbutylamine *(2)*

Hexylamine $(C_2H_5)_2CHCH_2NH_2$

2-Ethylbutylamine is a water-white liquid with an amine odor. It is soluble in methyl and ethyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. It dissolves in water and while soluble in hot paraffin and carnauba waxes, these solidify on cooling.

Flash point	70°F
Specific gravity at 20/20°C	0.776
Boiling range	121-125°C

Table 14.29: n-Heptylamine *(2)*

$C_7H_{15}NH_2$

n-Heptylamine is a water-white liquid with an amine odor. It is insoluble in water but soluble in ethyl and methyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. It dissolves hot paraffin and carnauba waxes, which solidify when cooled.

Flash point	130°C
Melting point	−23°C
Specific gravity at 20/20°C	0.779
Boiling range	150-160°C

Table 14.30: 2-Ethylhexylamine *(2)*

Octylamine $C_4H_9CH(C_2H_5)CH_2NH_2$

Octylamine is a water-white liquid with an amine odor. It is insoluble in water but soluble in methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. It dissolves hot paraffin and carnauba waxes, which solidify on cooling.

Flash point	135°F
Specific gravity at 20/20°C	0.792
Boiling range	165-169°C

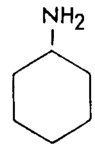
Table 14.31: Di-2-Ethylhexylamine *(2)*

Dioctylamine $[C_4H_9CH(C_2H_5)CH_2]_2NH$

Dioctylamine is a colorless liquid with a faintly amine odor. It is soluble in methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids. It is insoluble in water and while soluble in hot paraffin and carnauba waxes, these solidify when cooled. Among the large number of substances it will dissolve are natural and synthetic resins.

Boiling point (760 mm)	281.1°C	Solubility of water in solvent at 20°C	0.17% by wt.
Flash point	270°C	Vapor pressure at 20°C	0.01 mm
Specific gravity at 20/20°C	0.8062	Weight per gallon at 20°C	6.71 lbs.
Solubility in water at 20°C	0.02% by wt.	Boiling range	269-280°C

Table 14.32: Cyclohexylamine (2)

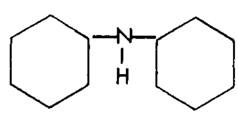


Cyclohexylamine is a colorless, caustic liquid with a fishy, amine odor. It has been known since 1893, but not until 1936 was it made in commercial quantities in the United States. It is produced by the catalytic hydrogenation of aniline. It is a strong base, even stronger than ammonia or the ethanol-amines. It is miscible with water and most of the common organic solvents, among which are the alcohols, ethers, ketones, esters, aliphatic and aromatic hydrocarbons, both pure and chlorinated. It is used as a solvent and as a corrosion inhibitor. Either alone or as a soap, it is employed as a wetting-out, cleansing, washing, emulsifying or dispersing agent in the textile industry. It may be used to absorb acidic gases, as a preservative for dyes, as an insecticide, and in the printing and dyeing of textile products.

Typical Properties and Specifications

Boiling point (760 mm)	134.5°C
Freezing point	−17.7°C
Fire point	30°C
Flash point	Below 0°C
Specific gravity at 25/25°C	0.8647
Refractive index at 25°C	1.4565
Weight per gallon at 20°C	7.206 lbs.
Azeotropic mixture	
Cyclohexylamine	44.2% by wt. B.P. (760 mm) 96.4°C
Water	55.8% by wt.
Distillation range	132.0–137.5°C

Table 14.33: Dicyclohexylamine (2)



Dicyclohexylamine is a clear, colorless and strongly basic liquid with a faint odor. It is miscible with most organic solvents but only slightly soluble in water. Unlike cyclohexylamine, it does not form an azeotropic mixture with water. It is more toxic than cyclohexylamine when absorbed through the skin and when large amounts are absorbed, death may result.

Dicyclohexylamine soaps are good emulsifying agents. This solvent may be used to absorb acidic gases, to preserve rubber latex, to plasticize casein, to neutralize plant and insect poisons, and as a solvent for dyes in the textile printing and dyeing industry.

Typical Properties and Specifications

Boiling point (760 mm)	255.8°C
Freezing point	−0.1°C
Fire point	160°C
Flash point	100°C
Specific gravity at 25/25°C	0.9104
Refractive index at 25°C	1.4823
Weight per gallon at 20°C	7.59 lbs.
Boiling range	252.0–258.0°C
Purity	98%, min.

Table 14.34: ALIQUAT Fatty Quaternary Ammonium Chloride *(58)*

Product	Aliquat 336*
Description	Methyl tricaprylyl ammonium chloride
Percent solids	88% minimum

*Aliquat is a registered trademark of Henkel Corp.

Table 14.35: KEMAMINE Fatty Quaternary Ammonium Chlorides *(26)*

Product	Description *(CTFA adopted name)*	% Active Min	% Amine Max	% Amine HCl Max	Color Gardner, 1963 Max
Kemamine Q-2802C*	Dimethyl Di-Behenyl *(Dibehenyl Dimonium Chloride)*	75	2	2	4
Kemamine Q-9702C	Dimethyl Di-Hydrogenated Tallow *(Quaternium-18)*	75	1.5	0.5	2
Kemamine Q-9743CHGW	Trimethyl Monoalkyl *(Tallow Trimonium Chloride)*	65	1.5	0.5	4
Kemamine Q-9743C	Trimethyl Monoalkyl *(Tallow Trimonium Chloride)*	65	1.5	0.5	4
Kemamine BQ-9742C	Dimethyl Tallow Benzyl *(Tallow Alkonium Chloride)*	75	1.5	0.5	6

*Semicommercial.

Product	Average molecular weight	pH of 5% solution Max	% Ash Max	Typical carbon chain composition							
				Saturated						Unsaturated	
				C_{14}	C_{16}	C_{18}	C_{20}	C_{22}	C_{24}	$C_{18:1}$	$C_{18:2}$
Kemamine Q-2802C*	690	9	0.2		2	5	10	80	3		
Kemamine Q-9702C	575	9	0.2	4	29	67					
Kemamine Q-9743CHGW	335-355	9	0.5	4	29	25				38	4
Kemamine Q-9743C	335-355	9	0.5	4	29	25				38	4
Kemamine BQ-9742C	420	9	0.2	4	29	25				38	4

*Semicommercial.

Table 14.36: High Molecular Weight Aliphatic Amines *(59)*

N-alkyl Chain	Carbon Chain Length	Primary																Secondary		Diamines			
		Armeen 8D	Armeen 10D	Armeen 12	Armeen 12D	Armeen 14D	Armeen 16D	Armeen H T	Armeen H T D	Armeen 18	Armeen 18D	Armeen T	Armeen T D	Armeen S	Armeen S D	Armeen C	Armeen C D	Armeen 2C	Armeen 2H T	Duomeen C	Duomeen C D	Duomeen S	Duomeen T
Hexyl	6	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Octyl	8	90	4	—	—	—	—	—	—	—	—	—	—	—	—	8	8	8	—	8	8	—	—
Decyl	10	7	90	2	2	—	—	—	—	—	—	—	—	—	—	9	9	9	—	9	9	—	—
Dodecyl	12	—	6	95	95	4	—	—	—	—	—	—	—	—	—	47	47	47	—	47	47	—	—
Tetradecyl	14	—	—	3	3	92	—	2	2	—	—	2	2	—	—	18	18	18	—	18	18	—	2
Hexadecyl	16	—	—	—	—	4	92	24	24	6	6	24	24	20	20	8	8	8	24	8	5	20	24
Octadecyl	18	—	—	—	—	—	7	71	71	90	90	28	28	17	17	5	5	10	75	5	5	17	28
Octadecenyl	18	—	—	—	—	—	1	3	3	4	4	46	46	26	26	5	5	—	1	5	5	26	46
Octadecadienyl	18	—	—	—	—	—	—	—	—	—	—	—	—	37	37	—	—	—	—	—	—	46	—
Mol. combining weight		135	166	213	195	227	250	300	275	300	280	298	274	297	275	223	208	450	530	321	310	402	400
Percent Primary Amine		90	—	82	94	92	95	85	95	85	95	85	95	86	95	85	95	—	—	40	44	40	40
Percent Secondary Amine		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	85	85	—	—	—	—
Approx. Melting Pt. °C		−13	8	24	24	29	38	57	55	55	55	46	41	31	22	24	21	46	68	22	20	40	46
Color—FAC		3	3	9	3	3	3	11	3	11	3	11	3	19	7	11	3	9	5	19	11	13	19
Grade: D—Distilled T—Technical		D	D	T	D	D	D	T	D	T	D	T	D	T	D	T	D	D	D	T	D	T	T

N-alkyl Chain	Carbon Chain Length	Dimethyl Tertiary Amine										Dialkyl Tertiary Amines		
		Armeen DM16	Armeen DM16D	Armeen DM18	Armeen DM18D	Armeen D M C	Armeen D M C D	Armeen D M S	Armeen D M S D	Armeen D M H T	Armeen D M H T D	Armeen M2HT	Armeen M2C	Armeen M2S
Hexyl	6	—	—	—	—	—	—	—	—	—	—	—	—	—
Octyl	8	—	—	—	—	8	8	—	—	—	—	—	8	—
Decyl	10	—	—	—	—	9	9	—	—	—	—	—	9	—
Dodecyl	12	—	—	—	—	47	47	—	—	—	—	—	47	—
Tetradecyl	14	—	—	—	—	18	18	—	—	2	2	2	18	—
Hexadecyl	16	92	92	6	6	8	8	20	20	24	24	24	8	20
Octadecyl	18	7	7	90	90	5	5	17	17	71	71	71	5	17
Octadecenyl	18	1	1	4	4	5	5	26	26	3	3	3	5	26
Octadecadienyl	18	—	—	—	—	—	—	37	37	—	—	—	—	37
Mol. weight—theoretical		271	271	295	295	224	224	289	289	289	289	522	389	520
Mol. combining weight		338	295	369	321	280	244	361	314	361	314	564	436	594
Percent Tertiary Amine		80	92	80	92	80	92	80	92	80	92	—	—	—
Approx. Melting Pt. °C		15	10	23	20	−10	−15	0	−8	17	15	28	−5	9
Color—Gardner—1933		5	1	5	1	5	1	10	1	5	1	—	—	—
D—Distilled T—Technical		T	D	T	D	T	D	T	D	T	D	T	T	T

Table 14.37: Solubilities of Pure Dodecyl- and Octadecyl-Trimethylammonium Chlorides in Grams per 100 Grams of Solvent *(59)*

Salt—Solvent		−10°	0°	10°	20°	30°	40°	45°	50°	55°	56.5°	60°	65°	70°	72°	80°	84°	86°
Dodecyl	Methanol	83.1	113.8	145.8	180	226.6	—	—	—	—	—	—	—	—	—	—	—	—
	Acetone	—	—	—	—	2.88	9.76	—	41.75	91.9	110.6	—	—	—	—	—	—	—
	Acetonitrile	—	4.8	10.9	18.2	32.8	81.2	—	—	—	—	—	—	—	—	—	—	—
	Carbon tetrachloride	—	—	—	—	1.21	34.2	102	gel	—	—	—	—	—	—	—	—	—
	Insoluble in ethyl acetate, benzene, n-hexane or cyclohexane at 95°.																	
Octadecyl	Methanol	5.7	15.4	32.5	71.6	112.8	168	—	252	—	—	—	—	—	—	—	—	—
	Ethanol(93.5%)	3.7	9.3	25.6	43.1	82.9	132	—	210	—	—	—	—	—	—	—	—	—
	Acetone	—	—	—	—	—	—	—	0.50	0.71	0.76	—	—	—	—	—	—	—
	Acetonitrile	—	—	—	0.7	1.8	3.2	—	5.1	—	—	9.9	—	32.7	—	78.6	—	—
	Carbon tetrachloride	—	—	—	—	—	—	—	—	0.40	—	5.04	36.2	—	—	—	—	—
	Chloroform	13.6	25	40.8	56	73.5	100	—	—	—	—	—	—	—	—	—	—	—
	Ethyl acetate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.22	5.04
	Benzene	—	—	—	—	—	—	—	—	0.5	—	3.1	19	46	—	—	—	—
	Insoluble in n-hexane or cyclohexane at 95°C.																	

Table 14.38: Solubilities of Organic Compounds in Aliphatic Amines at 25° ± 5°C *(1)(2)*

Abbreviation		Approx. Sol'y Range per 100 cc. of Solvent *Grams*
ins	Insoluble or extremely slightly soluble	(0^+ to 10)
ss	Slightly soluble	(10^+ to 40)
s	Moderately soluble	(40^+ to 70)
vs	Very soluble	(70^+ to 100)
vs+	More than vs	
es	Extremely soluble	(100^+ and above)
misc	Miscible (in methylamine column only)	
∞	Miscible in all proportions	
n	Not soluble to an appreciably greater extent in hot solvent	
x	More soluble in heated amine, crystallizes on cooling	
m	More soluble in heated amine (in some cases because of chemical reaction)	
p	Separates into two liquid phases	
r	Solute reacts chemically with solvent. Reaction is rapid enough to be apparent. All acidic substances react more or less rapidly with amines. (The letter *r* has been omitted in these cases)	
a	Swells	
Numerals	Numerals appearing in diethylamine column indicate number of grams of solute (or of its reaction product with diethylamine) per 100 cc. of solution	

		C_2H_5OH	$(C_2H_5)_2O$	CH_3NH_2	$(C_2H_5)_2NH$	$(C_2H_5)_3N$	$(n\text{-}C_3H_7)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_2NH$	$(n\text{-}C_4H_9)_3N$	iso-$C_5H_{11}NH_2$	$C_6H_5CH_2NH_2$	NH_3(−33° C.)
1	Acenaphthene	ssx	..	..	15	sx	..	sx	s	ssx	s	s	ins
2	Acetaldehyde	..	..	misc	..	..	..	..	..	..	..	..	..
3	Acetamide	s	..	vs	ssx	ins	..	s	ins	ins	s	s	vs
4	Acetanilide	vs	ss	..	11	ssx	..	vs	ss	ssx	sx	s	..
5	Acetic acid	..	..	vs	..	.	..	..	..	..	..	..	..
6	Acetoacetic ester	∞	..	..	∞	..	..	..	∞	..	..	..	∞
7	Acetone	∞	∞	∞	..	..	..	..	..	..	..	..	..
8	Acetophenone	∞	..	..	∞	..	.	∞	..	∞	..	..	s
9	*p*-Acetophenylene diamine	..	..	..	ins	..	..	ssx	ssx	..	ssx	..	..
10	*p*-Acetotoluide	ss	s	..	ss	..	..	..	..	ssx	ssx	..	ss
11	Acetylene	s	..	s	..	..	..	..	..	..	..	..	..
12	Acetylene tetrabromide	s	∞	..	r	..	..	..	..	..	..	..	s
13	Acetylsalicylic acid	vs	ss	..	s	s	s	vs	s	ss	vs	s	..
14	Agar-agar	..	..	..	..	..	..	..	..	..	insn	..	ins
15	Alanine	ss	ins	..	..	..	..	..	..	..	insn	..	..
16	Aldol	∞	s	..	∞	..	..	∞	..	..	..	..	..
17	Alizarin	..	..	s	..	..	..	..	..	..	..	..	..
18	Allyl alcohol	∞	∞	..	∞	..	..	..	..	..	..	..	..
19	1-Aminoanthraquinone	ss	ss	..	ss	ss	ss	ssm	ss	ssx	ssm	ss	..
20	*p*-Aminobenzoic acid	s	ss	..	ins	ins	isn	ss	ins	insn	ss	ssx	..
21	*m*-Aminophenol	s	s	..	vs+	ss	..	s	s	ss	vs	s	..
22	*o*-Aminophenol	ss	ss	..	vs	ins	s	vs+	sx	ssn	s	s	vs
23	Aminosulfonic (sulfamic) acid	..	..	..	..	..	..	ssn	..	..	ssx	..	..
24	Ammonium benzoate	..	..	..	ss	..	..	vsr	..	..	vsr	..	vs
25	Ammonium citrate	..	..	..	ss	..	..	..	..	..	..	..	..
26	Amyl alcohol (iso)	∞	∞	..	∞	..	..	∞	..	..	..	∞	..
27	*n*-Amyl formate	∞	∞	∞	..	..	..	..	..	∞	..	..	..
28	Anethole	∞	∞	..	∞	..	..	..	..	..	..	..	ss
29	Anhydroformaldehydeaniline	ss	ss	..	ssn	ssx	ins	ss	ss	ssx	ssx	ssx	..
30	Aniline blue	..	..	..	ss	ins	..	ss	ins	ins	ss	ss	..
31	Anthracene	ss	ss	..	ss	ssx	..	ssx	ss	ssx	ssx	ssx	ins
32	Anthranilic acid	s	s	..	ss	ins	ssx	s	ss	ss	s	s	..
33	Anthraquinone	ss	ss	ss	..	..	..	ssx	..	..	ssx	..	ins
34	Atoxyl	..	..	..	ins	ins	..	ss	ins	ins	ss	ins	..
35	Azobenzene	ss	s	vs	vs	vsx	vs	vs	vs	s	vs	s	s
36	Azoxybenzene	s	s	..	es	..	..	..	..	..	es	..	s
37	Beeswax	..	..	..	s	s	..	s	s	ssm	s	ssm	..
38	Benzalacetophenone	ss	vs	..	vs	..	..	es	..	ssx	..	..	..
39	Benzaldehyde	∞	∞	misc	∞	..	..	..	..	..	..	..	es
40	Benzamide	s	vss	..	ss	ins	s	s	ss	ins	s	s	vs
41	Benzene	∞	∞	..	∞	..	..	∞	∞	∞	..	∞	s
42	Benzidine	s	ss	..	ss	ss	..	s	ssx	ins	sx	s	..
43	Benzil	vs	vs	vs	vs	ss	sx	es	ss	ss	es	es	s
44	Benzoic acid	vs	vs	vs	ssx	ssx	..	vs	s	ssp	s	sx	vs+
45	Benzoic sulfinide (Saccharin)	ss	ins	r	..	..	..	..	..	..	ss	..	..
46	Benzoin	s	..	..	..	..	..	vs	..	..	..	..	..
47	Benzophenone	s	s	vs	es	es	..	es	vs+	sx	es	es	s
48	Benzyl acetate	∞	∞	..	∞	..	..	..	∞	..	..	∞	s
49	Benzyl alcohol	∞	∞	..	∞	..	..	..	..	∞	..	..	∞
50	Borneol	vs	vs	..	es	..	..	..	..	..	..	..	s
51	*o*-Bromoacetanilide	..	..	vs	..	..	..	..	..	..	..	..	..
52	*p*-Bromoaniline	vs	vs	..	esx	vs+	esx	vs+	vs	ssx	vs	vs+	..
53	Bromcamphor	s	vs	..	vs+x	s	..	vs+x	vs+	ssx	vs	vs	..
54	Bromocresol green	..	..	..	ss	ins	..	s	ssn	ins	s	s	..
55	1-Bromonaphthalene	∞	∞	..	∞	..	..	..	..	∞	..	..	..
56	*p*-Bromonitrobenzene	a	s	..	s	..	..	..	..	..	..	..	..
57	*o*-Bromotoluene	s	..	..	∞	..	..	..	∞	∞	..	∞	..
58	*p*-Bromotoluene	s	s	..	es	..	..	..	es	..	..	..	..
59	*n*-Butyl alcohol	∞	..	..	∞	..	..	..	..	..	∞	∞	∞
60	tert-Butyl alcohol	..	..	∞	..	..	..	..	..	..	..	..	..
61	*n*-Butyl xyanide	∞	s	..	∞	..	..	∞	..	..	∞	..	s
62	*n*-Butyl ether	∞	∞	..	∞	..	..	∞	∞	∞	∞	..	..
63	*n*-Butyl formate	∞	∞	..	∞	..	..	..	∞	..	..	..	..
64	*n*-Butyl stearate	..	..	..	∞	..	..	∞	∞	∞	∞	rss	..
65	Caffeine	ss	ss	..	ss	..	..	ssx	..	..	ssx	..	ss
66	Calcium acetate	ins	..	..	insn	..	..	..	..	..	..	..	..
67	*n*-Calcium butyrate	..	..	..	..	..	..	insn	..	..	..	..	..
68	Calcium formate	ins	..	..	..	..	..	..	..	..	insn	..	..
69	*d*-Camphor	es	vs	..	es	es	..	es	vs	vsx	es	es	vs
70	Carbon disulfide	∞	∞	..	r	..	..	esr	..	∞	..	..	r

(continued)

Table 14.38 (continued)

		C_2H_5OH	$C_2H_5 > O$ / C_2H_5	CH_3NH_2	$C_2H_5 > NH$ / C_2H_5	$(C_2H_5)_3N$	$(n\text{-}C_3H_7)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_2NH$	$(n\text{-}C_4H_9)_3N$	$iso\text{-}C_5H_{11}NH_2$	$C_6H_5CH_2NH_2$	$NH_3(-33°\ C.)$
71	Casein	..	..	..	ins	ins	..	ins	ins	ins	ins	ins	..
72	Cellulose	ins	ins	..	ins	ins	..	ins	ins	ins	ins	insa	ins
73	Cellulose acetate	..	..	..	ss	ins	ins	es	ins	ins	s	s	es
74	Cellulose nitrate	..	..	..	s	ins	..	vs	ss	ins	vs	vs	s
75	Cerulein	..	..	vs	..	..	..	..	..	..	..	..	..
76	Cetyl alcohol	s	s	vsx	..	..	..	es	..	s	..	..	ins
77	Chloroacetic acid (mono)	s	s	..	srx	vsxp	..	sx	ssxr	ssp	vs	ssrm	vs
78	p-Chlorodiphenyl	s	s	..	vs+	vs+x	..	vs	vs	sx	vs	vs	..
79	Chloroform	∞	∞	∞r	∞	..	..	..	..	..	..	..	sr
80	Cholesterol	ssx	s	..	..	..	vs+	..	..	..	vs+	..	ins
81	Chromotropic salt	..	..	..	..	..	..	insn	..	..	..	..	..
82	Cinchonine	ss	ss	..	..	..	..	ssn	..	..	ssx	..	ins
83	Cinnamic acid	s	vs	..	s	ss	..	sx	ss	ssx	s	ssx	s
84	Coconut oil	..	..	..	∞	∞	..	∞	∞	∞	∞	∞	..
85	Copal	..	..	..	..	..	..	..	..	..	insn	..	ss
86	Crystal violet	..	..	..	ins	ins	..	vs	ins	ins	s	s	s
87	Cyclohexanol	s	s	..	∞	..	..	..	..	..	..	..	..
88	o-Dianisidine (bianisidine)	s	vs	..	ss	ins	..	sx	ss	ins	s	s	..
89	Diazoaminobenzene	s	vs	..	vs	..	..	..	..	..	es	..	vs
90	p-Dibromobenzene	s	..	..	40	vs+x	..	vsx	vs	sx	vs	vs+	ss
91	2,3-Dibromopropyl alcohol	vs	∞	..	..	..	..	..	..	..	..	..	..
92	Dichloramine-T	..	..	..	vsr	sr	..	vsr	ssr	r	vsr	vs+r	r
93	p-Dichlorobenzene	es	vs	..	53	esx	..	es	ves	vs+x	esx	es	ss
94	Dichlorogallein	..	..	s	..	..	..	..	..	..	..	..	s
95	Dichlorohydrin	∞	∞	..	∞	..	..	..	..	..	..	..	..
96	2,3-Dihydroxyquinoxaline	..	..	..	..	..	..	insn	..	..	..	..	s
97	Dimethyalminoazobenzene	x	..	..	sx	ssx	ssx	sx	s	ss	s	s	..
98	p-Dimethylaminobenzaldehyde	s	s	..	..	..	..	sx	..	..	..	..	..
99	Dimethylaniline	s	∞	..	∞	..	..	..	..	..	..	..	ss
100	Dimethylethylcarbinol	s	s	..	∞	..	..	..	∞	..	∞	∞	..
101	Dimethylglyoxime	vs	vs	..	ssx	s	ssx	vs	ss	ssx	vs	s	..
102	2,6-Dimethylquinoline	vs	vs	..	vs	..	..	..	..	..	..	..	..
103	2,2-Dinaphthylamine	ss	..	..	ssx	ssx	ssx	sx	ssx	ssx	s	ss	..
104	2,4-Dinitroaniline	ss	..	vs	..	..	..	..	..	..	..	..	..
105	m-Dinitrobenzene	ssx	..	vs	9.3	ss	..	s	ss	ssx	s	s	..
106	3,5-Dinitrobenzoic acid	vs	ss	..	ss	ss	ssx	s	ss	ssx	vs	sm	..
107	4,4′-Dinitrodiphenyl	ss	vs	..	ss	ss	..	ssx	ssx	ssx	ssx	ssx	..
108	2,4-Dinitro-1-naphthol-7-sulfonic acid	..	..	..	ss	..	..	..	..	..	..	..	..
109	2,4-Dinitrophenol	ss	vs	..	ss	..	..	sx	..	ssn	vs	..	vs
110	2,4-Dinitrotoluene	ss	..	vs	sx	..	..	sx	ssx	ssx	..	..	ss
111	Diphenyl	ss	s	..	41	s	..	vs	s	sx	vs	vs	ss
112	Diphenylamine	vs	vs	..	es	vs	es	es	vs	sx	es	es	..
113	Diphenylbenzamide	..	..	..	ss	..	..	..	..	..	ssx	..	..
114	Diphenylguanidine	..	..	..	ss	ins	..	vs	s	ssx	vs	s	..
115	Diphenyl ketoxime	..	..	vs	..	..	..	..	..	..	..	..	..
116	Diphenyl sulfone (phenyl sulfone)	ss	s	..	ssx	ssx	..	ssx	ss	ssx	ssx	sx	..
117	Diphenylurea (sym.)	s	s	..	ss	ins	..	ss	ss	ssx	s	ssx	s
118	4,4′-Dipyridyl (bipyridine)	vs	..	..	..	..	..	vsx	..	..	sx	..	vs
119	Di-p-tolylselenide	..	..	..	..	..	..	es	..	..	..	..	..
120	Eosin	s	..	..	ss	ins	..	vs	ss	ins	vs	s	s
121	Ethyl alcohol	∞	∞	..	..	..	..	..	∞	..	..	∞	..
122	Ethyl carbonate	s	..	..	ssr	..	..	∞	..	..	..	∞	sr
123	Ethyl cyanoacetate	∞	∞	..	∞	..	..	..	..	..	..	..	..
124	Ethylene dibromide	s	∞	spr	∞	..	..	..	∞	..	..	∞	..
125	Ethylene glycol	∞	ss	..	∞	..	∞	..	..	..	∞	..	..
126	Ethyl iodide	s	s	..	∞	..	..	..	..	∞	..	esr	s
127	Ethyl malonate	∞	∞	..	∞	..	..	..	∞	..	∞	..	..
128	Ethyl oxalate	s	..	..	∞	..	..	..	∞	..	..	ssr	..
129	Ethyl sulfate	..	..	..	r	..	..	..	rs	..	..	..	..
130	Fluorene	ss	vs	..	13	ssx	sx	s	s	ssx	s	s	ins
131	Fluorescein	vs	ss	..	ss	ins	..	s	ins	ins	s	s	s
132	Galactose	ss	..	vs	..	..	..	..	..	..	..	..	..
133	Gallein	..	..	ss	..	..	..	..	..	..	..	..	..
134	Gallic acid	s	ss	..	insn	insn	..	s	insx	insn	s	ssm	s
135	Gelatin	..	..	..	ins	ins	..	insn	ins	ins	ins	ins	..
136	Glucose	ss	ins	vs	ss	ins	ssn	vs+	ins	ins	s	s	vs
137	β-Glucose pentaacetate	ss	ss	..	..	..	..	es	..	..	..	..	..
138	Glycerol	∞	ins	vs	..	..	..	..	..	..	..	..	..
139	Guaiacol	∞	∞	..	∞	..	..	..	..	..	..	..	..
140	Guanidine nitrate	..	..	..	ss	..	..	..	..	..	..	..	vs
141	Gum arabic	..	..	..	insn	ins	..	ins	ins	ins	ssn	ss?	..
142	H acid	ss	ss	..	..	..	..	insn	..	..	..	..	..
143	Hemoglobin	..	..	..	ins	..	..	insn	..	..	..	..	ss
144	Hexaethylbenzene	s	vs	..	..	..	..	ssx	..	..	ssx	..	..
145	Hexamethylenetetramine	ss	ins	..	ssn	..	..	ssn	..	..	..	..	..
146	Hippuric acid	ss	vss	vs	ssx	..	..	..	..	..	vs	..	vs
147	Hydrazine sulfate	ins	..	..	ins	..	..	..	..	..	..	..	insr
148	Hydroquinone	vs	vs	vs	35	ss	s	s	s	ss	s	ssx	vs
149	Hydroxylamine hydrochloride	s	ins	vs	..	..	..	..	..	..	..	..	..
150	Indigotin	ins	ins	vs	ins	ins	..	ss	ss	ss	ins	ss	ss

(continued)

Table 14.38: (continued)

		C_2H_5OH	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>O$	CH_3NH_2	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>NH$	$(C_2H_5)_3N$	$(n\text{-}C_3H_7)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_2NH$	$(n\text{-}C_4H_9)_3N$	$iso\text{-}C_5H_{11}NH_2$	$C_6H_5CH_2NH_2$	$NH_3(-33°\ C.)$
151	Indole	vs	vs	..	es	..	..	es	..	..	..	..	vs
152	Isatin	s	ss	..	..	..	..	vs	..	..	..	..	s
153	Isoquinoline	∞	∞	..	∞	..	..	..	∞	..	∞	..	s
154	Lactose	ss	ins	..	ss	ss	..	ss	ins	ins	es	ins	vs
155	Lanolin	..	..	..	es	es	..	es	es	es	es	es	..
156	Linseed oil, raw	..	..	..	∞	∞	..	∞	∞	∞	∞	∞	..
157	Lysol	..	..	..	∞	..	..	..	..	..	..	..	..
158	Maleic acid	s	ss	..	ins	ins	..	ssn	ins	ins	sex	insm	..
159	Malic acid	vs	ss	..	ins	ins	ins	ssn	ins	ins	ssn	ssx	ss
160	Malonic acid	s	ss	..	ins	insn	insx	ss	ins	ss?	ss	ins	ins
161	Mannite	ss	ins	..	ss	ins	..	ss	ins	ins	ssn	ins	ss
162	d-Menthol	vs	vs	..	es	es	es	es	es	es	es	es	es
163	Mercuric acetate	ss	..	..	insr	ins	s	vs	ss	ins	ss	ins	s
164	Mercuric cyanide	s	..	vs	..	..	..	es	..	ssn	..	..	vs
165	Mercury diphenyl	ss	..	..	ss	ins	ss	ss	ss	ins	ss	ins	..
166	Mercury di-p-tolyl	..	..	..	..	..	..	ssx	..	ssx	ssx	..	..
167	Methanol	∞	∞	∞	..	..	..	∞	..	∞	..	..	..
168	meso-Methyl acridine	vs	vs	..	..	..	..	..	..	..	es	..	..
169	Methylene aminoacetonitrile	..	..	..	ss	ss	...	ss	ins	ssx	ss	ins	..
170	Methylene dianiline	..	..	..	insn	ss	..	ss	ss	insx	ss	ss	..
171	Methyl orange	ss	ins	ss	ins	ins	ins	ssn	ins	ins	ss	ss	..
172	Mucic acid	ins	..	..	ins	ins	insn	ss	ins	ins	ss	ins	s
173	Naphthalene	ss	vs	..	27	sx	..	vsx	s	sx	vs	sx	ss
174	Naphthionic acid	ss	ins	..	ss	ins	..	s	ins	ins	s	ss	..
175	1-Naphthol	vs	vs	vs	..	..	..	..	..	..	..	..	..
176	2-Naphthol	vs	vs	vs	es	vs+	..	es	es	vs	es	es	ss
177	Naphthol yellow	..	..	..	ins	ins	..	ss	ins	ins	ins	ins	..
178	Night blue	..	..	..	s	s	..	s	s	s	s	s	..
179	p-Nitroacetanilide	s	ss	..	ss	..	..	..	..	..	..	..	..
180	m-Nitroaniline	s	ss	..	sx	ssx	..	s	ss	ssx	s	s	s
181	p-Nitroaniline red	..	..	..	ss	ss	..	s	ssx	ssx	s	s	..
182	m-Nitrobenzaldehyde	vs	vs	vs	..	..	..	..	..	..	..	..	..
183	Nitrobenzene	∞	∞	∞	..	..	..	∞	..	∞	..	..	vs
184	m-Nitrobenzenesulfonamide	..	..	vs	..	..	..	..	..	..	..	..	..
185	o-Nitrobenzoic acid	s	s	vs	..	..	..	..	..	..	..	..	..
186	p-Nitrobenzoic acid	ss	ss	..	ssx	insn	ssx	vsx	ss	ss	s	sx	ss
187	p-Nitrobromobenzene	ss	..	..	ss	ss	ssx	sx	ss	ssx	s	sx	..
188	o-Nitrophenol	vs	vs	vs	..	..	..	..	..	..	..	..	..
189	p-Nitrophenol	vs	s	..	13	ss	ssx	vs	ss	ssm	vs	s	s
190	p-Nitrophenylhydrazine	..	..	..	..	..	..	vs	..	ssx	..	..	..
191	o-Nitrotoluene	∞	∞	vs	..	..	..	..	...	..	..	..	..
192	p-Nitrotoluene	s	s	..	vs+x	..	..	..	..	sx	vsx	..	..
193	3-Nitro-4-toluidine	vs	..	..	sx	..	..	vsx	..	ssx	..	..	s
194	Nitrourea	vs	vs	..	ins	..	..	..	..	..	..	..	vs
195	Oleic acid	∞	∞	..	∞	∞	..	∞	∞	∞	∞	∞	ins
196	Olive oil	..	..	..	∞	∞	..	∞	∞	∞	∞	∞	..
197	Orange IV	..	..	..	ss	ins	..	ss	ss	ins	ssn	ss	..
198	Oxalic acid.$2H_2O$	s	ss	..	ins	ins	..	insn	insn	ins	ins	ins	ins
199	Oxanilide	ss	ss	..	0.5	..	..	..	..	..	..	..	..
200	Palmitic acid	ss	..	vs	..	..	..	..	..	..	..	..	..
201	Paraffin	..	..	..	ss	sx	..	s	sm	sx	s	ssx	ins
202	Paraffin oil	..	..	..	∞	..	..	∞	..	∞	..	..	..
203	n-Pentane	∞	..	∞	..	..	..	..	..	..	..	..	..
204	2-Pentene	..	..	..	∞	..	..	..	..	..	..	..	..
205	Penacetin	ss	ss	..	ss	ins	ssx	s	ss	ssx	s	ss	..
206	Phenanthrene	ss	s	..	s	..	..	..	..	..	..	vs	ins
207	Phenol	∞	∞	vs	es	..	..	..	..	..	es	..	vs
208	Phenolphthalein	s	ss	vs	s	ss	..	s	ss	ss	s	s	..
209	Phenylacetic acid	es	vs	vs	..	..	..	vsx	..	..	..	..	..
210	meso-Phenyl acridine	ss	s	..	..	..	..	..	..	..	ssx	..	..
211	Phenylazo-1-naphthylamine	..	..	..	..	..	..	..	..	ssx	s	..	..
212	o-Phenylenediamine	vs	vs	..	..	..	..	sx	..	..	sx	..	vs
213	Phenylglucosazone	ss	..	..	..	..	..	sx	..	..	vs	..	vs
214	Phenylhydrazine	∞	∞	∞	..	..	..	..	..	..	..	..	..
215	Phenylmercuric bromide	..	..	..	..	..	..	ssx	..	..	ssx	..	..
216	2-Phenylquinoline	vs	vs	..	vs	..	..	vs	..	..	s	..	..
217	Phenyl-p-tolyl sulfone	..	..	..	6.3	ins	ins	ss	ss	ssx	ssx	ss	..
218	Phenyl urea	vs	vs	..	ss	ss	ssn	s	ss	ssx	vs	s	s
219	Phthalic acid	s	ss	ins	ins	ins	..	ins	ins	insx	..	ssx	ins
220	Phthalic anhydride	s	ss	ins	sm	ss	..	s	ss	ins	s	ssm	..
221	Phthalimide	s	ss	..	s	ss	ss	s	sx	ssm	s	s	vs
222	Picric acid	s	ss	vs	ssp	ss	vs	vs+	s	ssx	vs	s	es
223	Potassium amide	r	ins	..	ins	..	..	insn	..	..	..	..	vs
224	Potassium ethyl sulfate	..	..	..	ins	..	..	..	..	..	..	..	vs
225	Potassium quinaldine	r	vs	..	..	..	..	vs	..	..	..	..	es
226	Potassium triphenylmethyl	r	s	..	..	..	..	s	..	..	..	..	..
227	Pyridine	∞	∞	∞	..	..	..	..	..	..	..	..	∞
228	Pyrogallol	vs+	vs+	vs	ssm	ss	...	s	s	ss	s	sm	es
229	Pyrrole	vs	vs	..	∞	..	..	..	..	..	..	..	..
230	Quinaldine	vs	vs	..	∞	..	..	∞	..	∞	∞	..	s
231	Quinaldine picrate	ss	..	..	es	..	..	es	vsx	ss	..	..	..
232	Quinine	es	vs+	..	s	ssm	s	vs	ssm	ss	vs	s	insf
233	Quinoline	s	..	..	∞	..	...	∞	∞	∞	..	∞	∞
234	Quinoline methiodide	..	..	..	..	..	..	vsx	..	..	vs	..	vs
235	Quinoline yellow (water soluble)	..	..	..	ins	ins	..	ss	ss	ins	ssn	ss	..
236	Quinone	vs	vs	sr	vsr	..	..	..	..	..	..	..	..
237	Resorcinol	es	vs	vs	s	..	..	vs	..	..	..	..	es
238	Rosaniline	s	ins	vs	ins	ins	..	ss	ins	ins	ss	ss	s
239	Rosin	vs	vs	..	s	s	..	vs	vs	ins	s	s	insr
240	Rosolic acid	ss	s	..	ss	ss	..	s	ss	ss	s	s	ss

Table 14.39: Vapor Pressure of Various Amines *(37)*

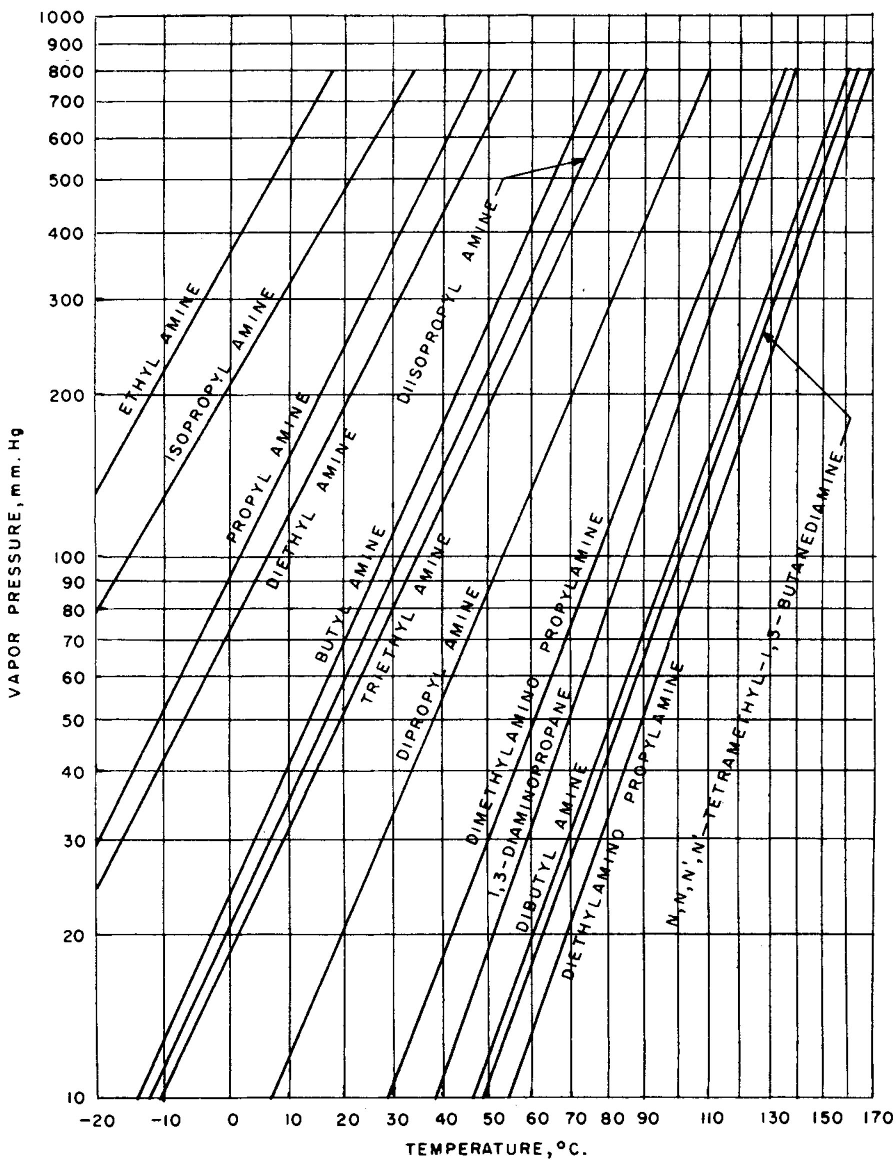
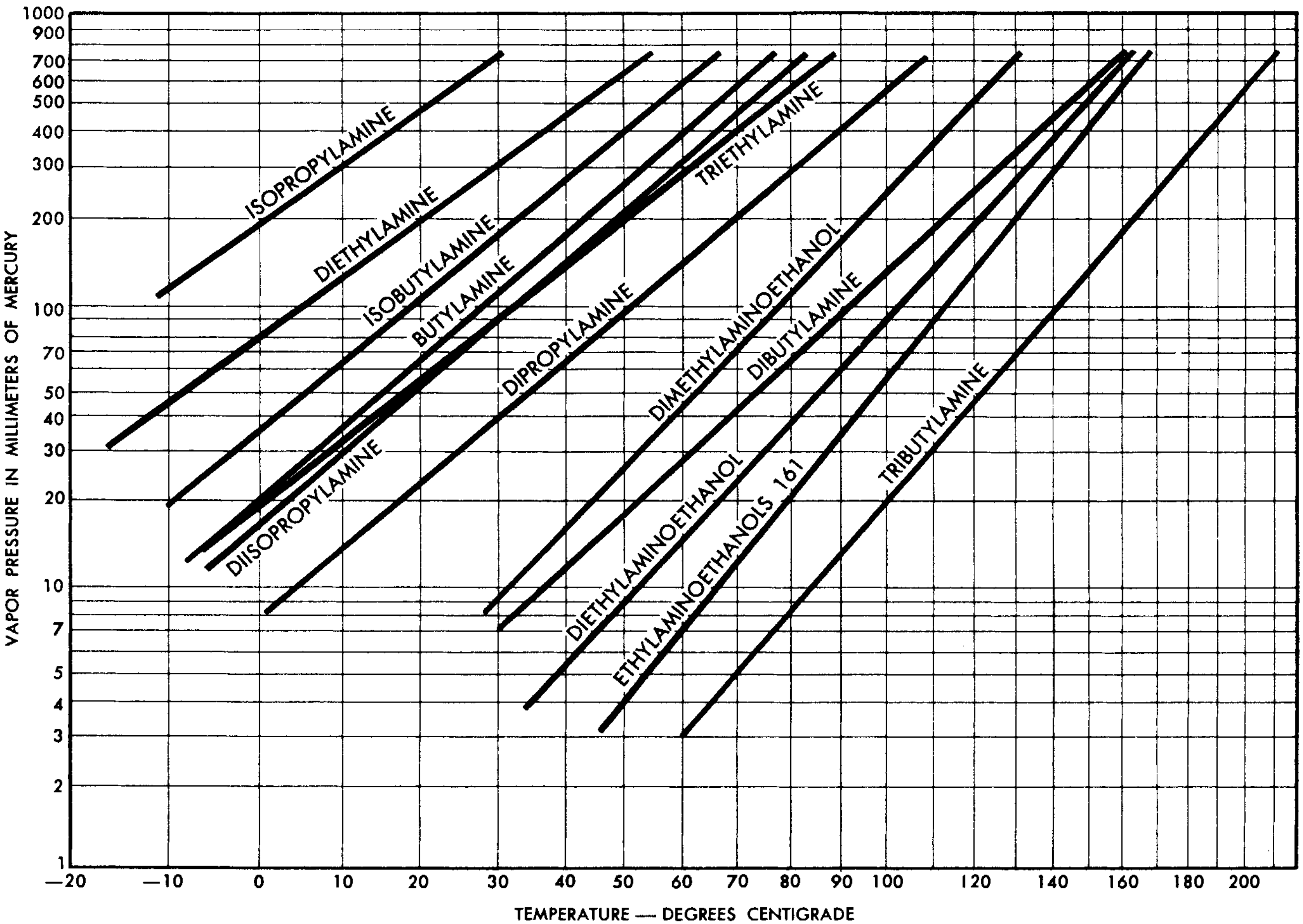


Table 14.40: Vapor Pressure of Sharples Amines *(37)*



ALKYLENE DIAMINES

Table 14.41: Ethylene Diamine *(2)*

$NH_2CH_2CH_2NH_2$

Ethylenediamine is a water-white, hygroscopic liquid with a strong ammoniacal odor. The commercial product is a 78% solution of ethylenediamine by weight. It is used in the synthesis of organic rubber accelerators, insecticides, textile processing chemicals, emulsifiers, plastics and pharmaceuticals. It is also used as a corrosion inhibitor.

	78% solution
Boiling point (760 mm)	117.2°C
Dielectric constant at 18°C	16.0
Flash point (open cup)	110°F
Heat of combustion	425.6 cal./mol
Heat of solution at 15°C	7.6 cal./mol
Ionization constant at 25°C	7.1×10^{-4}
Latent heat of evaporization	167 cal./g.
Latent heat of fusion (0°C)	77 cal./g.
Melting point	11.0°C
Specific gravity at 20/20°C	0.8995
Solubility in water at 20°C	Complete
Solubility of water in solvent at 20°C	Complete
Refractive index at 26°C	1.4540
Vapor pressure at 20°C	10.7 mm
Viscosity at 25°C	0.0154 poise
Weight per gallon at 20°C	7.49
Constant-boiling mixture	
Ethylenediamine	80% by wt. B.P.°C
Water	20% by wt. 118.5
Boiling range (760 mm)	115 to 122°C
Color	Water-white
Purity	78% by wt.

Table 14.42: Boiling Point Composition Curves for Aqueous Ethylenediamine Solutions *(2)*

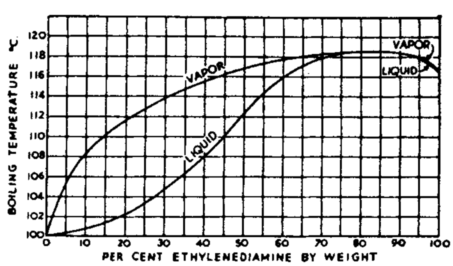


Table 14.43: Diethylenetriamine *(2)*

$NH_2CH_2CH_2NHCH_2CH_2NH_2$

Diethylenetriamine is a colorless liquid, completely miscible with water and many organic solvents. It is a solvent for sulfur, acid gases, numerous natural resins and dyes. It is also used in organic synthesis and as a saponification agent for acidic materials.

Boiling point (760 mm)	207.1°C
Flash point (open cup)	215°F
Specific gravity at 20/20°C	0.9542
Vapor pressure at 20°C	0.03 mm
Weight per gallon at 20°C	7.94 lbs.

Table 14.44: Boiling Point Composition Curves for Aqueous Diethylenetriamine Solutions *(2)*

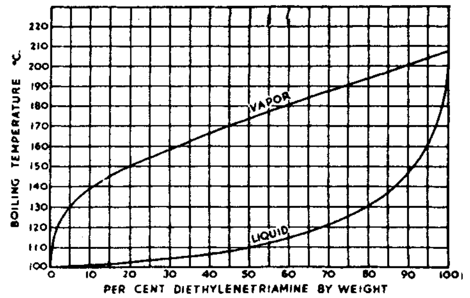


Table 14.45: Tetraethylenepentamine *(2)*

$NH_2(CH_2CH_2NH)_3CH_2CH_2NH_2$

Tetraethylenepentamine is a viscous, hygroscopic and high-boiling liquid. It is miscible with water and many organic solvents, and is a solvent for dyes, resins, sulfur, and acid gases. It also forms soaps with fatty acids and it is employed in the synthesis of emulsifiers, plastics, and in rubber reclaiming.

Boiling point (760 mm)	333°C
Flash point	325°F
Specific gravity at 20°C	0.998
Vapor pressure at 20°C	0.01 mm
Weight per gallon at 20°C	8.31 lbs.
Boiling range (760 mm)	320°-360°C

Table 14.46: Propylenediamine *(2)*

1,2-Diaminopropane $CH_3CH(NH_2)CH_2NH_2$

Propylenediamine is a water-white liquid with an ammoniacal odor. It is miscible with water and many organic solvents, among them being benzene and naphtha. It does not form a constant-boiling mixture with water. It is a solvent for such substances as cellulose nitrate, castor oil, shellac, pine oil, copal gum, rosin, and dyes.

It behaves much like ethylenediamine but it is considered superior in solvent power. It is used in the manufacture of gasoline additives.

Boiling point (760 mm)	119.7°C
Flash point (open cup)	120°F
Specific gravity at 20/20°C	0.8732
Solubility in water at 20°C	Complete
Solubility of water in solvent at 20°C	Complete
Vapor pressure at 20°C	9.4 mm
Weight per gallon at 20°C	7.27 lbs.
Boiling range (760 mm)	112-122°C
Purity	80% by wt. min.

Table 14.47: Solvent Properties of Alkylene Diamines *(2)*

	ETHYLENE DIAMINE	PROPYLENE DIAMINE	TRIETHYLENE TETRAMINE	MORPHOLINE	MORPHOLINE ETHANOL	MORPHOLINE ETHYL ETHER
Water	M	M	M	M	M	M
Alcohol	M	M	M	M	M	M
Glycols	M	M	M	M	M	M
Glycol ethers	M	M	M	M	M	M
Acetone	M	M	M	M	M	M
Methyl butyl ketone	S	S	S	M	M	M
Ethyl ether	S	S	S	M	M	M
Butyl ether	SS	S	SS	M	M	M
Naphtha	S	S	SS	S	I	M
Benzene	M	M	S	M	M	M
Turpentine	I	I	I	M	M	M
Pine oil	M	M	M	M	M	M
Paraffin oil	I	I	I	I	I	M
Castor oil	M	M	M	M	M	M
Linseed oil	I	I	I	M	S	M
Paraffin wax	SH	SH	SH	SH	SH	SS
Beeswax	I	I	SH	I	I	SS
Shellac	S	S	S	S	S	S
Rosin	S	S	S	S	SS	S
Ester gum	SS	SS	SS	S	S	S
Dammar gum	I	I	I	PS	PS	S
Copal gum	S	S	S	S	S	S
Sulfur	VS	VS	S	SS	SS	SS
Vinylite A	G	G	G	S	G	SS
Vinylite N	S	S	S	S	S	S
Vinylite 0200	G	G	G	S	G	S
Cellulose acetate	G	G	G	S	S	I
Cellulose nitrate	S	S	S	S	S	S
Benzyl cellulose	SS	SS	SS	S	S	S
Water-sol. dye	S	S	SS	I	I	I
Alcohol-sol. dye	S	S	S	S	S	S
Oil-sol. dye	S	S	S	S	S	S
Satd. brine	M	M	M	M	M	S

M = miscible in all proportions
S = sol. to over 5%
SS = sol. from 1 to 5%
PS = sol. in part
I = sol. to less than 1%
SH = sol. hot
VS = very sol.
G = gels.

Table 14.48: Vapor Pressures of Alkylene Diamines and Other Amines *(19)*

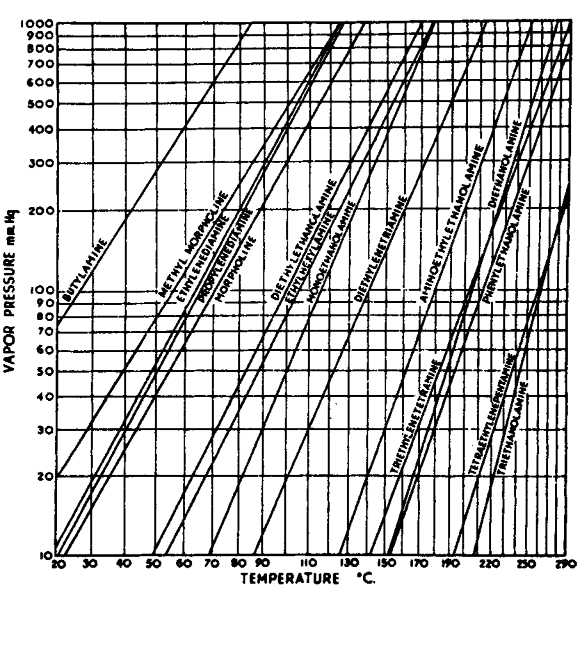


Table 14.49: Density of Ethylenediamine Solutions *(23)*

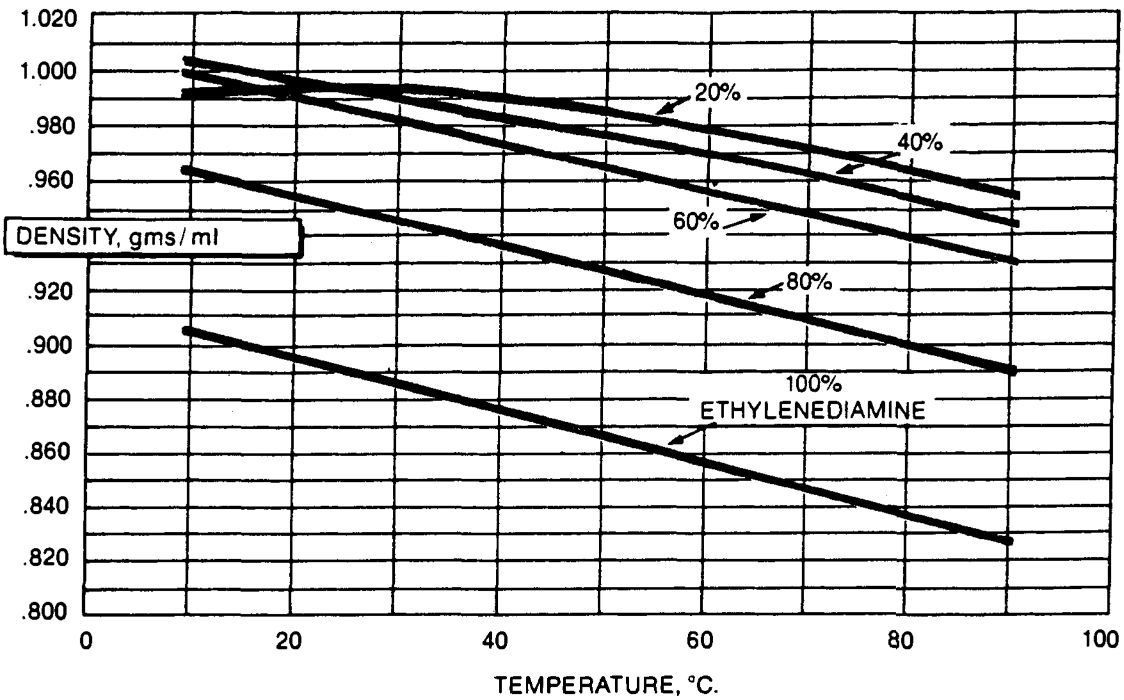


Table 14.50: Density of Higher Ethylene Amines *(23)*

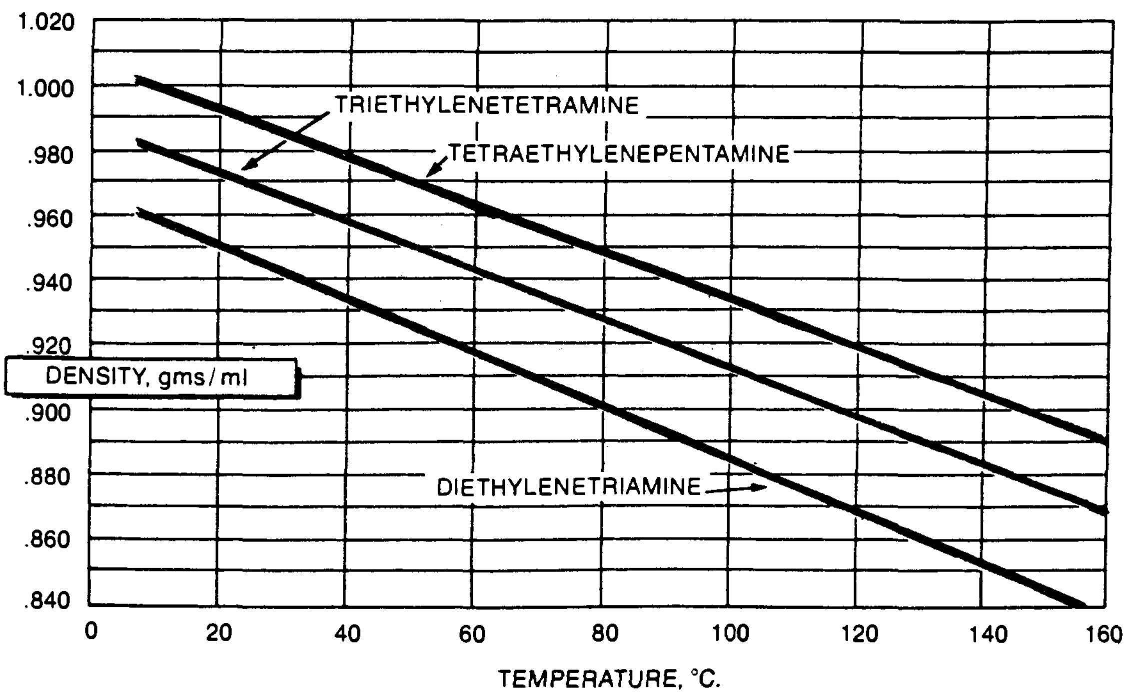


Table 14.51: Viscosity of Ethylenediamine Solutions *(23)*

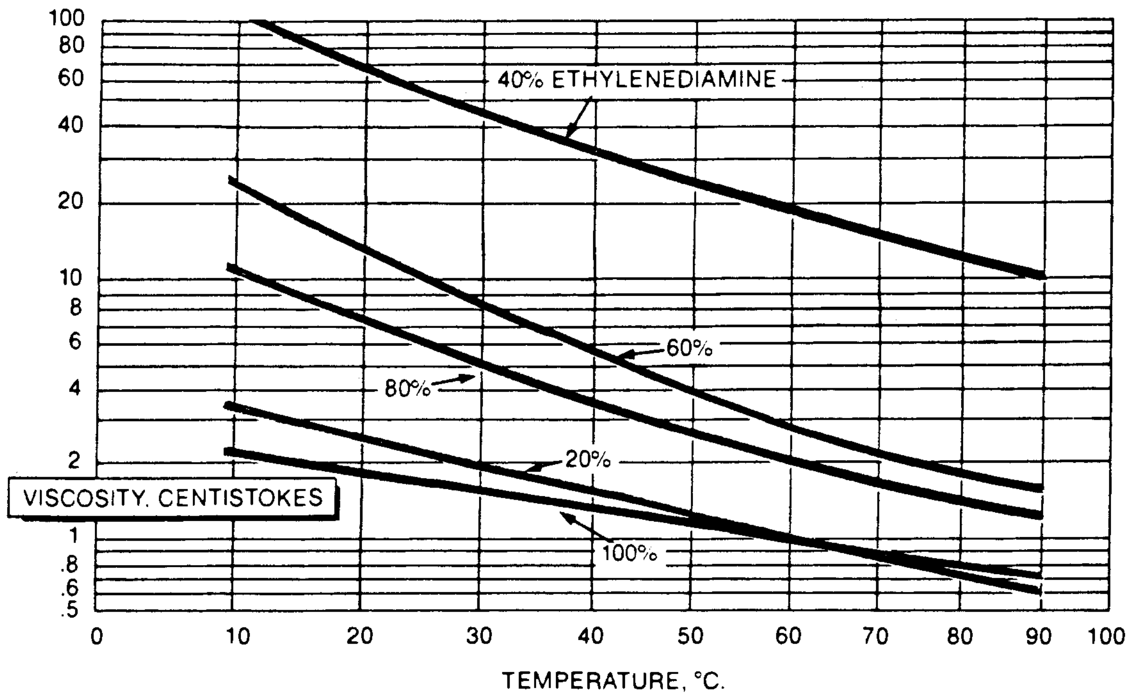
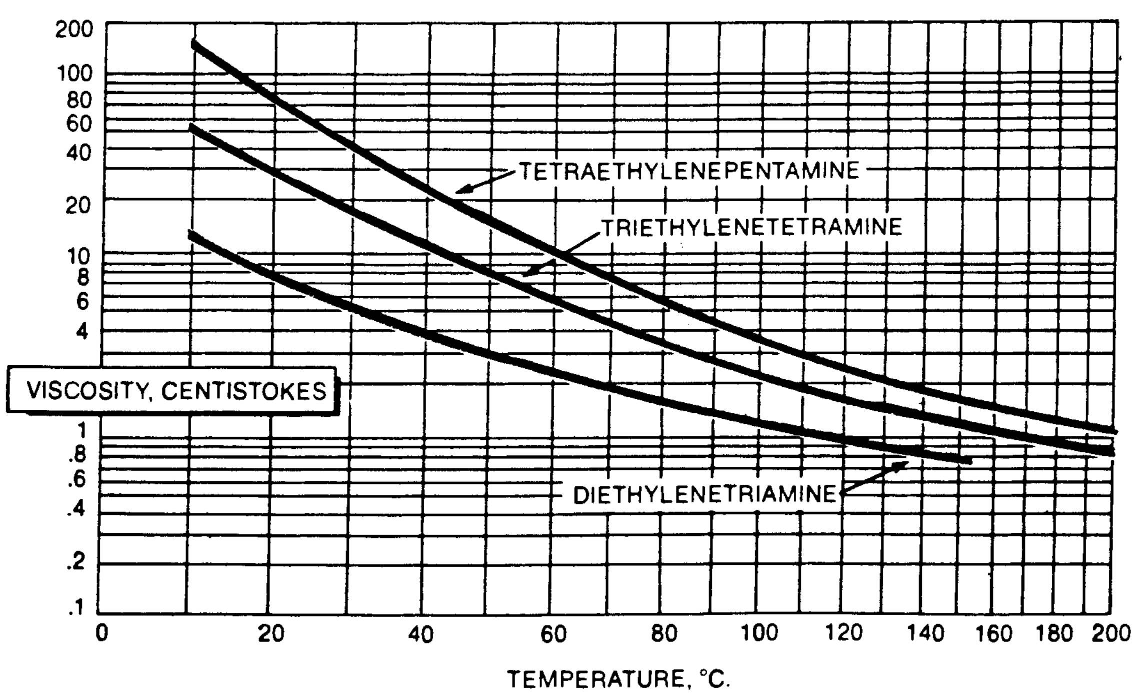


Table 14.52: Viscosity of Higher Ethylene Amines *(23)*



COMPARATIVE DATA

Table 14.53: Akzo ARMEEN, DUOMEEN, TRIAMEEN, ETHOMEEN, Ethoxylated Diamines, Propoxylated Amines *(59)*

Armeen Primary Amines

Registered Tradename	Common Name*	SPECIFICATIONS: TSCA Number	SPECIFICATIONS: Primary Amine, % Min.	SPECIFICATIONS: Amine Number Min.	SPECIFICATIONS: Gardner Color Max.	SPECIFICATIONS: Moisture % Max.	TYPICAL PROPERTIES: Equivalent Weight**	TYPICAL PROPERTIES: Melting Point, °C	TYPICAL PROPERTIES: Primary Amine, %	TYPICAL PROPERTIES: Amine Number	TYPICAL PROPERTIES: Iodine Value
Armeen 12D	Dodecylamine	124-22-1	98	297	1	0.5	186	24	99.5	303	0.5
Armeen 16D	Hexadecylamine	143-27-1	98	228	1	0.5	243	48	99	231	1
Armeen 18D	Octadecylamine	124-30-1	98	204	1	0.5	270	55	99	208	2
Armeen O	Oleylamine	112-90-3	97	205	3	0.5	266	24	98	211	89
Armeen OD	Oleylamine	112-90-3	98	207	1	0.5	265	23	99	212	89
Armeen OL	Oleylamine	112-90-3	95	202	4	0.5	273	20	97	206	89
Armeen OLD	Oleylamine	112-90-3	98	207	1	0.5	265	21	100	212	89
Armeen C	Cocoalkylamine	61788-46-3	97	272	3	0.5	204	16	98	275	9
Armeen CD	Cocoalkylamine	61788-46-3	98	275	1	0.5	200	16	100	281	9
Armeen S	Soyaalkylamine	61790-18-9	97	206	4	0.5	273	29	97	206	92
Armeen SD	Soyaalkylamine	61790-18-9	98	208	2	0.5	264	29	100	213	92
Armeen T	Tallowalkylamine	61790-33-8	97	208	3	0.5	267	40	98	210	46
Armeen TD	Tallowalkylamine	61790-33-8	98	210	1	0.5	262	40	100	214	46
Armeen HT	Hydrogenated tallowalkylamine	61788-45-2	97	207	3	0.5	271	55	98	207	3
Armeen HTD	Hydrogenated tallowalkylamine	61788-45-2	98	209	1	0.5	263	55	100	213	3

Armeen Secondary Amines

Registered Tradename	Common Name*	SPECIFICATIONS****: TSCA Number	SPECIFICATIONS****: Apparent Secondary Amine, % Min.	SPECIFICATIONS****: Amine Number Min.	SPECIFICATIONS****: Gardner Color Max.	TYPICAL PROPERTIES: Equivalent Weight**	TYPICAL PROPERTIES: Melting Point, °C	TYPICAL PROPERTIES: Secondary Amine, %	TYPICAL PROPERTIES: Amine Number	TYPICAL PROPERTIES: Iodine Value
Armeen 2C	Dicocoalkylamine	61789-76-2	93	140	2	401	43	92	140	8
Armeen 2T	Ditallowalkylamine	68783-24-4	93	110	2	507	55	94	111	33
Armeen 2HT	Dihydrogenated tallowalkylamine	61789-79-5	93	110	2	510	62	91	110	3
Armeen 2-18	Dioctadecylamine	112-99-2	93	107	2	518	80	89	108	1

*Common name may be different from the name listed by TSCA.
**Equivalent Weight = 56,110/Amine Number
***D = Distilled
****All secondary amines meet moisture specifications of 0.5% max.

(continued)

Table 14.53: (continued)

Armeen Tertiary Amines

Armeen Monoalkyl Amines

		SPECIFICATIONS**				TYPICAL PROPERTIES			
Registered Tradename	Common Name***	TSCA Number	Tertiary Amine, % Min.	Amine Number Min.	Gardne Color Max.	Equivalent Weight	Melting Point, °C	Amine Number	Tertiary Amine, %
	Monoalkyl-dimethylamines:								
Armeen DM12D****	Dodecyl-dimethylamine	112-18-5	95	250	1	218	-15	258	98
Armeen DM16D	Hexadecyl-dimethylamine	112-69-6	95	198	1	276	8	203	98
Armeen DM18D	Octadecyl-dimethylamine	124-28-7	95	180	1	303	20	185	98
Armeen DMOD	Oleyl-dimethylamine	28061-69-0	95	183	1	295	-10	190	98
Armeen DMCD	Cocoalkyl-dimethylamine	61788-93-0	95	234	1	236	-22	239	98
Armeen DMSD	Soyaalkyl-dimethylamine	61788-91-8	95	183	2	297	-10	189	98
Armeen DMTD	Tallowalkyl-dimethylamine	68814-69-7	95	184	1	291	5	193	98
Armeen DMHTD	Hydrogenated tallowalkyl-dimethylamine	61788-95-2	95	184	2	292	18	192	98

Armeen Dialkyl Amines

		SPECIFICATIONS**				TYPICAL PROPERTIES			
Registered Tradename	Common Name***	TSCA Number	Tertiary Amine, % Min.	Amine Number Min.	Gardne Color Max.	Equivalent Weight	Melting Point, °C	Amine Number	Tertiary Amine, %
	Dialkyl-methylamines:								
Armeen M2C	Dicocoalkyl-methylamine	61788-62-3	97	137	2	395	-2	142	99
Armeen M2HT	Dihydrogenated tallowalkyl-methylamine	61788-63-4	97	105	1	524	38	107	99

Armeen Trialkyl Amines

		SPECIFICATIONS**				TYPICAL PROPERTIES			
Registered Tradename	Common Name***	TSCA Number	Tertiary Amine, % Min.	Amine Number Min.	Gardne Color Max.	Equivalent Weight	Melting Point, °C	Amine Number	Tertiary Amine, %
	Trialkylamines:								
Armeen 3-12	Tridodecylamine	102-87-4	95	102	1	540	-9	104	96
Armeen 3-16	Trihexadecylamine	67701-00-2	98	82	3	668	38	84	99

(continued)

Table 14.53: (continued)

Polyamines

Duomeen Diamines

Registered Tradename	Common Name*	TSCA Number	Amine Number (SPECIFICATIONS)	Gardner Color	Iodine Value	Moisture %	Equivalent Weight (TYPICAL PROPERTIES)	Appearance @ 25 °C	Amine Number
			Min.	Max.	Min.	Max.			
Duomeen C	N-coco-1,3-diaminopropane	61791-63-7	410	5	–	1.0	133	Liquid	422
Duomeen CD	N-coco-1,3-diaminopropane	61791-63-7	410	3	–	1.0	130	Liquid	432
Duomeen T	N-tallow-1,3-diaminopropane	61791-55-7	334	5	30	1.0	161	Paste	348
Duomeen TTM	N,N,N'-trimethyl-N'-tallow-1,3-diaminopropane	68783-25-5	271	8	–	1.0	199	Liquid	282
Duomeen OL	N-oleyl-1,3-diaminopropane	7173-62-8	320	10	70	1.0	163	Liquid	344
Duomeen LT-4	3-tallowalkyl-1,3-hexahydropyrimidine	EPA Listed	267	8	–	0.5	200	Liquid	281
Duomeen S	N-Soyaalkyl trimethylenediamines	61791-67-1	312	12	60	1.0	160	Soft Paste	350

Higher Amines

Registered Tradename	Common Name*	TSCA Number	Amine Number (SPECIFICATIONS)	Gardner Color	Iodine Value	Moisture %	Equivalent Weight (TYPICAL PROPERTIES)	Melting Point	Amine Number
			Min.	Max.	Min.	Max.			
Triameen T	N-tallowalkyl dipropylene triamine	61791-57-9	415	8	–	0.5	133	34	422
Tetrameen T	N-tallowalkyl tripropylene tetramine	68911-79-5	475	6	25-35	0.5	114	37	492

*Common name may be different from the name listed by TSCA.

Ethomeen Ethoxylated Amines

Registered Tradename	Common Name***	TSCA Number	Equivalent Weight (SPECIFICATIONS**)		Gardner Color	Primary plus Secondary Amine, %	Amine Number (TYPICAL PROPERTIES)	Appearance @ 25 °C
			Min.	Max.	Max.			
Ethomeen C/12	Ethoxylated (2) cocoalkylamine	61791-31-9	280	300	6	3	193	Liquid
Ethomeen C/15	Ethoxylated (5) cocoalkylamine	61791-14-8	410	435	7	2	133	Liquid
Ethomeen C/20	Ethoxylated (10) cocoalkylamine	61791-14-8	620	660	10	1	88	Liquid
Ethomeen C/25	Ethoxylated (15) cocoalkylamine	61791-14-8	830	890	10	1	65	Liquid
Ethomeen O/12	Ethoxylated (2) oleylamine	13127-82-7	343	363	8	3	160	Liquid

(continued)

Table 14.53: (continued)

Registered Tradename	Common Name***	TSCA Number	Equivalent Weight Min.	Equivalent Weight Max.	Gardner Color Max.	Primary plus Secondary Amine, %	Amine Number	Appearance @ 25 °C
		SPECIFICATIONS**					TYPICAL PROPERTIES	
Ethomeen O/15	Ethoxylated (5) oleylamine	58253-49-9	470	495	8	2	116	Liquid
Ethomeen T/12	Ethoxylated (2) tallowalkylamine	61791-44-4	340	360	6	3	160	Paste
Ethomeen T/15	Ethoxylated (5) tallowalkylamine	61791-26-2	470	495	7	2	116	Liquid to Paste
Ethomeen T/25	Ethoxylated (15) tallowalkylamine	61791-26-2	890	950	8	1	61	Liquid to Paste
Ethomeen S/12	Ethoxylated (2) soyaalkylamine	61791-24-0	342	362	10	3	159	Liquid
Ethomeen S/15	Ethoxylated (5) soyaalkylamine	61791-24-0	470	495	10	2	116	Liquid
Ethomeen S/20	Ethoxylated (10) soyaalkylamine	61791-24-0	685	725	10	1	80	Liquid
Ethomeen S/25	Ethoxylated (15) soyaalkylamine	61791-24-0	895	955	10	1	61	Liquid
Ethomeen 18/12	Ethoxylated (2) octadecylamine	10213-78-2	350	370	7	3	156	Solid
Ethomeen 18/15	Ethoxylated (5) octadecylamine	26635-92-7	480	505	8	2	114	Solid
Ethomeen 18/20	Ethoxylated (10) octadecylamine	26635-92-7	690	730	8	1	79	Liquid to Paste
Ethomeen 18/25	Ethoxylated (15) octadecylamine	26635-92-7	900	960	8	1	60	Liquid to Paste
Ethomeen 18/60	Ethoxylated (50) octadecylamine	26635-92-7	2370	2570	10	0.5	23	Paste to Solid

Ethoduomeen Ethoxylated Diamines

Registered Tradename	Common Name***	TSCA Number	Equivalent Weight Min.	Equivalent Weight Max.	Primary plus Secondary Amine, % Max.	Equivalent Weight	Appearance @25 °C
	SPECIFICATIONS					TYPICAL PROPERTIES	
Ethoduomeen T/13	Ethoxylated (3) N-tallow-1,3-diaminopropane	61790-85-0	220	250	2	239	Liquid
Ethoduomeen T/20	Ethoxylated (10) N-tallow-1,3-diaminopropane	61790-85-0	375	405	2	144	Liquid
Ethoduomeen T/25	Ethoxylated (15) N-tallow-1,3-diaminopropane	61790-85-0	485	515	2	112	Liquid

Propomeen Proxylated Amines

Registered Tradename	CAS Name	TSCA Number	Equivalent Weight Min.	Equivalent Weight Max.	Gardner Color Max.	Tertiary Amine, % Min.	Amine Number	Appearance @25 °C
		SPECIFICATIONS*					TYPICAL PROPERTIES	
Propomeen C/12	N-cocoalkyl-1,1'-iminobis-2-propanol	68516-06-3	308	318	5	95	179	Hazy Liquid
Propomeen O/12	N-oleyl-1,1'-iminobis-2-propanol	65086-71-7	371	391	6	97	147	Clear Liquid
Propomeen T/12	N-tallowalkyl-1,1'-iminobis-2-propanol	68951-72-4	373	383	5	95	148	Clear Liquid

(continued)

Table 14.53: (continued)

ARMEEN Aliphatic Amines

TRADE NAME	CTFA ADOPTED NAME	FORM	CONC (%) (APPROX.)
Armeen CD	Cocamine	Liquid	98
Armeen 2C	Dicocamine	Solid	90
Armeen DMCD	Dimethyl Cocamine	Liquid	95
Armeen DMMCD	Dimethyl Cocamine	Liquid	95
Armeen 12D	Lauramine	Liquid	95
Armeen DM12D	Dimethyl Lauramine	Liquid	95
Armeen 16D	Palmitamine	Solid	98
Armeen DM16D	Dimethyl Palmitamine	Liquid	95
Armeen 18D	Stearamine	Solid	90
Armeen DM18D	Dimethyl Stearamine	Liquid	95
Armeen SD	Soyamine	Paste	98
Armeen DMSD	Dimethyl Soyamine	Liquid	95
Armeen TD	Tallow Amine	Solid	98
Armeen HTD	Hydrogenated Tallow Amine	Solid	98
Armeen DMHTD	Dimethyl Hydrogenated Tallow Amine	Liquid	95
Armeen 2HT	Hydrogenated Ditallow Amine	Solid	92
Armeen OD	Oleamine	Paste	98

ETHOMEEN Ethoxylated Aliphatic Amines

TRADE NAME	CTFA ADOPTED NAME	FORM	CONC (%) (APPROX.)
Ethomeen C/12	PEG - 2 Cocamine	Liquid	99
Ethomeen C/15	PEG - 5 Cocamine	Liquid	99
Ethomeen C/20	PEG - 10 Cocamine	Liquid	99
Ethomeen C/25	PEG - 15 Cocamine	Liquid	99
Ethomeen 18/12	PEG - 2 Stearamine	Solid	99
Ethomeen 18/15	PEG - 5 Stearamine	Solid	99
Ethomeen 18/20	PEG - 10 Stearamine	Liquid to Paste	99
Ethomeen 18/25	PEG - 15 Stearamine	Liquid to Paste	99
Ethomeen 18/60	PEG - 50 Stearamine	Paste to Solid	99
Ethomeen O/12	PEG - 2 Oleamine	Liquid	99
Ethomeen O/15	PEG - 5 Oleamine	Liquid	99
Ethomeen O/25	PEG - 15 Oleamine	Liquid	99
Ethomeen S/12	PEG - 2 Soyamine	Viscous Liquid	99
Ethomeen S/15	PEG - 5 Soyamine	Liquid	99
Ethomeen S/20	PEG - 10 Soyamine	Liquid	99
Ethomeen S/25	PEG - 15 Soyamine	Liquid	99
Ethomeen T/12	PEG - 2 Tallow Amine	Paste	99
Ethomeen T/15	PEG - 5 Tallow Amine	Liquid to Paste	99
Ethomeen T/25	PEG - 15 Tallow Amine	Liquid to Paste	99

(continued)

Table 14.53: (continued)

Solubilities of Normal Saturated Primary Fatty Amines in Various Solvents

All temperatures are in degrees Centigrade.
Solubilities are in g/amine per 100 g/solvent.

Benzene

No. of Carbon Atoms in Amines	10°	20°	30°	40°	50°
10	395	∞	∞	∞	∞
12	72	277	∞	∞	∞
14	26.4	83	302	∞	∞
16	10.0	30.7	98	388	∞
18	4.2	14.8	52	173	1000

Cyclohexane

	10°	20°	30°	40°	50°
10	318	∞	∞	∞	∞
12	57	230	∞	∞	∞
14	19.9	68	268	∞	∞
16	7.4	26.6	86	360	∞
18	2.8	13.2	42.9	144	940

Tetrachloromethane

	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	10.5	57	∞	∞	∞	∞
12	5.5	19.8	148	∞	∞	∞
14	2.3	7.7	56	235	∞	∞
16	0.5	3.2	21.2	73	335	∞
18	<0.1	0.6	7.7	27.9	120	835

Trichloromethane

	−40.0°	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	17.7	43.0	148	∞	∞	∞	∞
12	9.2	20.0	56	315	∞	∞	∞
14	4.5	11.2	29.5	110	308	∞	∞
16	2.4	6.6	17.0	56	117	378	∞
18	1.2	3.3	9.4	31.9	63	149	845

Ethyl Ether

	−40.0°	−20.0°	0.0°	20.0°	30.0°	34.5°
10	1.4	12.1	86	∞	∞	∞
12	0.2	3.4	22.6	275	∞	∞
14		0.2	5.8	71	273	705
16			0.2	18.5	72	135
18				4.4	22.7	46.8

Ethyl Acetate

	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	14.8	69	∞	∞	∞	∞
12	4.7	18.6	211	∞	∞	∞
14	1.7	7.8	57	233	∞	∞
16	0.3	3.2	19.7	63	295	∞
18		0.9	9.5	27.0	100	845

Butyl Acetate

	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	13.3	69	∞	∞	∞	∞
12	4.4	23.0	221	∞	∞	∞
14	1.4	9.7	62	233	∞	∞
16	0.2	3.5	23.9	64	295	∞
18		1.0	11.4	30.4	100	845

Acetone

No. of Carbon Atoms in Amines	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	6.6	54	∞	∞	∞	∞
12	0.3	8.1	266	∞	∞	∞
14		0.1	15.5	228	∞	∞
16			<0.1	4.7	445	∞
18				<0.1	3.7	17.0

2-Butanone

	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	10.0	65	∞	∞	∞	∞
12	3.6	18.6	290	∞	∞	∞
14	0.2	2.8	48	285	∞	∞
16			8.3	48	580	∞
18			0.2	6.3	85	1975

Methanol

	−40.0°	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	31.0	172	550	∞	∞	∞	∞
12	4.8	29.7	196	930	∞	∞	∞
14	=0.2	2.8	62	292	770	∞	∞
16		0.2	6.1	116	256	785	∞
18			0.6	15.6	95	256	1440

Ethanol

	−40.0°	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	8.5	91	350	∞	∞	∞	∞
12	2.0	14.1	115	660	∞	∞	∞
14		1.5	30.2	218	660	∞	∞
16			3.0	83	239	770	∞
18			0.1	7.2	75	280	1630

Isopropanol

	−40.0°	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	11.1	49.0	228	∞	∞	∞	∞
12	4.7	15.0	75	492	∞	∞	∞
14	0.6	3.7	25.1	154	458	∞	∞
16		0.4	7.3	68	169	580	∞
18			0.5	30.0	86	228	1330

n-Butanol

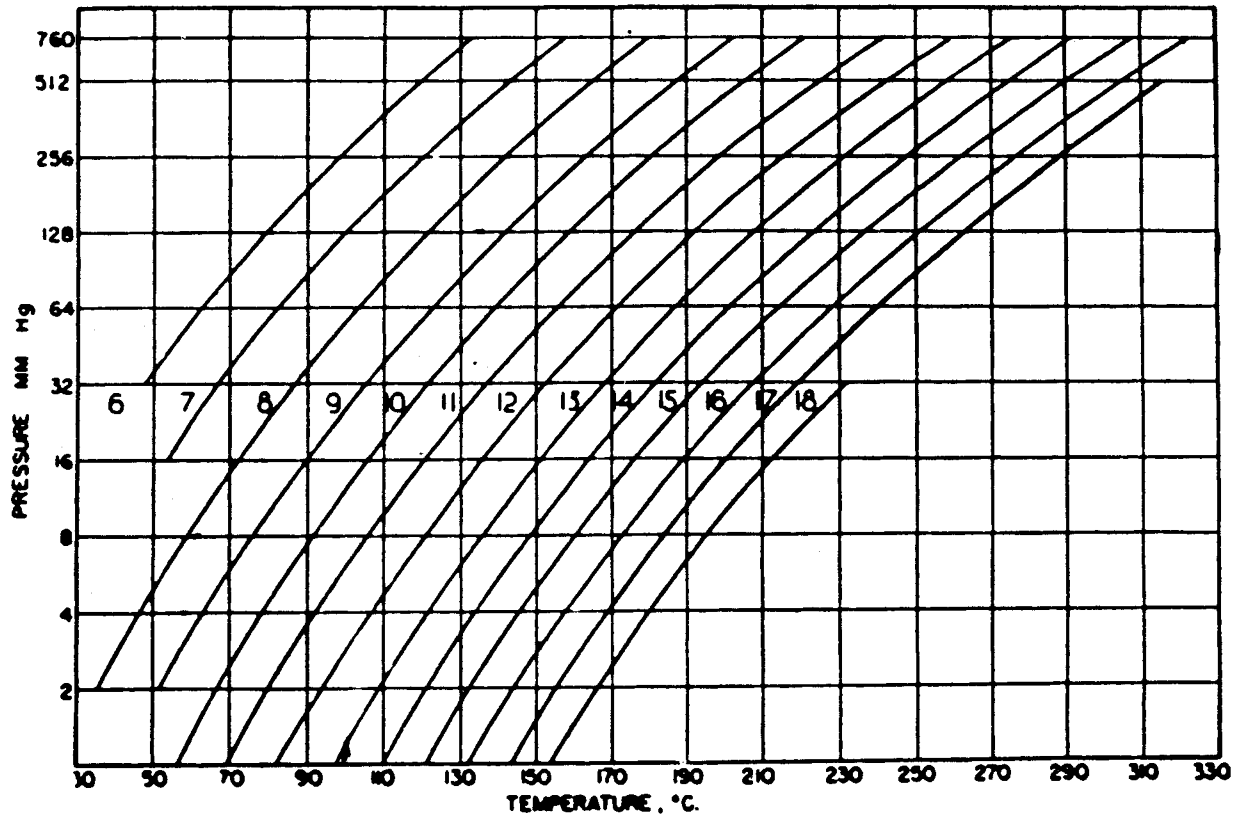
	−40.0°	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	9.5	30.8	182	∞	∞	∞	∞
12	2.4	8.5	57	430	∞	∞	∞
14	0.2	2.4	16.5	130	405	∞	∞
16		<0.1	3.9	55	148	515	∞
18			0.4	22.7	75	208	1240

Acetonitrile

	−20.0°	0.0°	20.0°	30.0°	40.0°	50.0°
10	2.8	12.7	∞	∞	∞	∞
12		0.2	27.7	∞	∞	∞
14			1.8	14.9	∞	∞
16			0.2	1.3	14.8	∞
18				0.3	1.9	10.5

(continued)

Table 14.53: (continued)



Vapor Pressure Curves of Normal Saturated Primary Amines

Approximate Alkyl Percent Distribution for Fine Amine Chemicals*

Alkyl Groups	10	12	16	18	O	OL	C	S	T	HT
Alkyl Composition	decyl-	dodecyl-	hexadecyl-	octadecyl-	oleyl-	oleyl-	coco	soya	tallow	hydrogenated tallow
Saturated										
C8	4						6			
C10	90	1					7			
C12	6	95			0.5	0.5	51	0.5		
C14		3			1.5	1.5	19	1.0	3	3.5
C15			0.5						0.5	0.5
C16		1	91	9	4	4	9	16.0	29	31
C17			1.5	2	0.5	0.5			1	1
C18			7	87	14	8	2	15.0	20	61
Unsaturated										
C14′					0.5	0.5			0.5	
C16′					4	4		1.0	2	
C18′				2	70	74	6	49.5	44	3
C18″					5	7		13		

*Composition is that of base acids from which amines were derived.

The chemical name in each table indicates the major alkyl group or the source of each alkyl mixture for every product.

The table gives additional information about the alkyl distribution of all products.

The tradename includes the source for each product; for example, Armeen 18 is octadecylamine.

The alkyl group in Armeen Z is derived from cocamine.

Table 14.54: ANGUS Amines *(34)*

Amine CS-1135®

Principal component	78% by weight in water
Appearance	Colorless to pale yellow mobile liquid
Boiling point	70–72°C at 100 torr
Neutral equivalent (calc)	120–126
Density at 26°C	0.942g/ml
pH of 0.1M soln. (20°C)	11.0

Soluble at >50% by wt. in water; ethyl alcohol; benzene; mineral spirits

Amine CS-1246™

Principal component	97.5% minimum
Appearance	Colorless to pale yellow mobile liquid
Boiling point	73–75°C at 10 torr
Neutral equivalent (calc)	143
Density at 26°C	1.072g/ml
pH of 0.1M soln. (20°C)	10.2

Soluble at >50% by wt. in water; ethyl alcohol; benzene; mineral spirits

ZOLDINE® ZT-55

Principal component	55% solution in water
Appearance	Colorless to pale yellow mobile liquid
Melting point	54.5°C (active component)
Neutral equivalent	273–278
Density at 25°C	1.125g/ml
pH of 0.1M soln. (20°C)	9.4

Active ingredient soluble at >50% by wt. in water; ethyl alcohol; at 25 g/100 ml in benzene at 25°C; at 1.2 g/100 ml in mineral spirits[1] at 75°C.

[1] when anhydrous

Typical Properties of AMINE CS-1135

Amine component	78% by wt
Neutral equivalent as a base	120-126
Color, APHA	100 (max)
Flash point, Tag closed cup	120°F
Freezing point	below −20°C
Specific gravity at 25/25°C	0.98-0.99
Viscosity at 25°C	~7.5 cp
pH	10.5-11.5
Weight per U.S. gallon	8.2 lb

Typical Physical Properties of CS-1246

Specific gravity, 30/20°C	1.085
Boiling point, °C at 15 mmHg	71
Freezing point, °C	0
Surface tension, dynes/cm at 25°C	36.5
pH	8-9

Soluble in water, ethanol, benzene, chlorinated hydrocarbons, and acetone

Flash point, Tag closed cup, °F	175

Specifications

Purity, % by wt.	97.5 min.
Total Oxazolidines, % by wt.	99.5 min.
Color, APHA	100 max.
Water, % by wt.	0.5 max.

Table 14.55: Ashland Amines *(69)*

Product	Specific Gravity	Distillation °C	Amine % by wt Based on Total Alkalinity	Color Pt-Co Scale Max	Flash Point °F Open Cup	Freezing Point °C	Lb. per Gal. at 20°C
AMP-95	0.942		95	28	172	−2	7.85 (25°C)
Butyl Amine	0.742-0.747	76.0-81.0	97.0	15	30	−49	6.20
Cyclohexylamine	0.8645-0.8655 (25°/25°C)	Approx. 134.5	98	20	72	−18	7.19 (25°C)
Dibutyl Amine	0.760	155-163	98	15	124	−62	6.32
Diethanolamine	1.090-1.094	Approx 187 (50mm)	98.5	15	280	28.0	9.14
Diethyl Amine	0.705-0.709	54.0-59.5	98.5	15	<0	−50	5.88
Diethylene Triamine	0.953-0.958	195-215	89.0-93.0	30	215	−39	7.98
Diethylethanolamine	0.885	157-165	99.5	15	120(CC)		
Diisopropyl Amine	0.715-0.720	Approx. 84.1	98.0	15	21	−96	5.97
Dimethylethanolamine	0.888	130-135	99	20	103(CC)	−59	
Isopropyl Amine	0.686-0.690	30.5-34.0 (90 ml. min.)	99.0	15	<0	−95	5.73
Methyldiethanolamine	1.04	242-260	99	250	259	−22.5	8.68
Monoethanolamine	1.016-1.019	166.0-174.0		15	200	10.3	8.47
Morpholine	1.001-1.004	126.0-130.0	99.0	10	102		8.37
Triethanolamine	1.1220-1.1300	Approx. 360	85.0	50	355	21.6	9.37
Triethanolamine, 99%	1.1240-1.1270		99.0	50	375	21.6	9.37
Triethyl Amine	0.726-0.730	85.0-91.0	99.0	15	20	−115	6.06

Table 14.56: Chemcentral Amines *(67)*

AMINES		CAS	Mole Weight	% Purity Comm. Prod.	Specific Gravity 25/25°C	Lbs. Per Gal. @ 25°C	Coeff. of Expan. Per °C	ΔSpec. Gravity Per °C	Refractive Index @ 25°C
AMP-95[c]		124-68-5			0.942	7.85	.00096		
AMP REGULAR[c]		124-68-5			0.928[d]	7.78[d]	.00095		1.449
DIETHANOLAMINE (DEA)		111-42-2	105.3	98.0	1.088 30/4°C	9.09 @ 30°C	.00060	.00040	1.475 @ 30°C
DIISOPROPANOLAMINE		110-97-4	133.0		0.992 40/4°C	8.28 @ 40°C			1.4595 @ 30°C
DI-TRI ISOPROPANOLAMINE			**139.5**		**1.006 20/4°C**	**8.37**	**.00070**	**.00034**	**1.4601**
MONOETHANOLAMINE (MEA)		141-43-5	61.4	97.5 Min.	1.015	8.45	.00079	.00058	1.4525
MONOISOPROPANOLAMINE		78-96-6	75.2	97	0.960	7.99	.00086	.00060	1.4456
MORPHOLINE		110-91-8	87.1	99	0.999	8.32	.00096	.00072	1.4545 @ 20°C
TRIETHANOLAMINE (TEA)		102-71-6	149.2	85	1.121	9.33	.00053	.00036	1.4836
TRIETHANOLAMINE 99%		**102-71-6**	**149.2**	**99**	**1.124**	**9.35**			
TRIISOPPOPANOLAMINE		122-20-3	191.0		1.010 40°C	8.44 @ 40°C			
ETHYLENEDIAMINE	EDA	107-15-3	60.1	99	0.901	7.45			1.455
DIETHYLENETRIAMINE	ETA	111-40-0	103.2	99	0.949	7.89			1.483
TRIETHYLENETETRAMINE	TETA	112-24-3	146.2		0.977	8.13			1.496
TETRAETHYLENEPENTAMINE	**TEPA**	**112-57-2**	**189.3**		**0.922**	**8.26**			**1.503**
DIETHYLAMINOETHANOL		100-37-8	117.2	99	0.8851†	7.40†			
DIETHYLAMINE		109-89-7	73.14	99.4	0.7079†	5.87†			
ETHYLAMINOETHANOL		110-73-6	89.16		0.914†	7.62†			
TRIETHYLAMINE		121-44-8	101.2	100	0.729†	6.08†			

*20 mm Hg **5 mm Hg † @ 20/20°C [a]Open Cup [b]Centistokes [c]Trade Mark Angus [d] @ 40/40°C

AMINES		Boiling Range 5-95% @ 760 mm Hg		Vapor Press. @ 25°C mm Hg	Viscosity CPS @ 25°C	Solubility % by Wt. @ 25°C		Freeze Point °C	Fire Point °F	Flash Point °F
		°C	°F			In H_2O	Of H_2O			
AMP-95[c]		100-165	212-329		147			−2		172
AMP REGULAR[c]		156-177	313-351			∞	∞	31		
DIETHANOLAMINE (DEA)		168-169*	334-336*	< .01	351.9 (30°C)	∞	∞	28	300	305
DIISOPROPANOLAMINE		119-123**	246-253**		870 (30°C)	1200	∞	47	275	250
DI-TRI ISOPROPANOLAMINE		**100-274****	**212-525****		**980**	**∞**	**∞**	**−23**	**245**	**>197**
MONOETHANOLAMINE (MEA)		170-172	338-342	0.36	18.95	∞	∞	10	200	195
MONOISOPROPANOLAMINE		159-163	318-325	0.51	23.0	∞	∞	3		165
MORPHOLINE		126-130	259-266	7.0	2.23 (20°C)	∞	∞	−5		100
TRIETHANOLAMINE (TEA)		175-191**	347-376**	< .01	590.5	∞	∞	18	410	365
TRIETHANOLAMINE 99%					**600.7**	**∞**	**∞**	**20**	**420**	**385**
TRIISOPPOPANOLAMINE						> 500		60		320
ETHYLENEDIAMINE	EDA	115-119	239-246		1.56[b]	∞	∞	11	100	100
DIETHYLENETRIAMINE	ETA	199-207	390-405		6.00[b]	∞	∞	−35	210	210
TRIETHYLENETETRAMINE	TETA	260-290	500-554		20.00[b]	∞	∞	< −40	310	270
TETRAETHYLENEPENTAMINE	**TEPA**	**155-210**	**311-410**		**52.50[b]**			**< −40**	**385**	**340**
DIETHYLAMINOETHANOL		162.1	324			∞	∞			130
DIETHYLAMINE		55.5	132			∞	∞	−49		< 0
ETHYLAMINOETHANOL		162-169	324-336			∞	∞			160
TRIETHYLAMINE		85-91	185-196			∞	∞	−114		< 20

Table 14.57: Dow Commercial Alkanolamines *(23)*

Properties of Dow Commercial Alkanolamines†

Property	MEA	DEA	TEA 85	TEA 99	MIPA	DIPA	TIPA	Isopropanolamine Mixture
Equivalent Wt.	61.4	105.3	142.0	148.6	75.2	133.0	191.0	139.5
Boiling Point, °C(°F), 760mm Hg	171 (340)	268 (514)	325 (617)	340 (644)	159 (318)	249 (480)	306 (583)	214 (417)
Freezing Point, °C,°F	10 (50)	28 (82.4)	17 (62.6)	21 (69.8)	3[1] (37.4)	44[1] (111.2)	44[1] (111.2)	24[1] (75.2)
Specific Gravity, 25/4°C.	1.0113	1.0881 (30/4°C)	1.1179	1.1205	0.960 (20/4°C)	0.992 (40/4°C)	0.988 (70/4°C)	1.003
Lbs/Gal, 25°C	8.45	9.09 (30°C)	9.34	9.35	7.95	8.27 (40°C)	8.24 (70°C)	8.36
Refractive Index N_d, 25°C	1.4525	1.4750 (30°C)	1.4836	1.4839	1.4456	1.4595 (30°C)	—	1.4601
Viscosity, cps, 25°C	18.9	351.9 (30°C)	590.5	600.7	23.0	870.0 (30°C)	—	950
60°C	5.0	53.8	65.6	65.8	6.0 (54°C)	86.0 (54°C)	100	68 (54°C)
Flash Point, °F	201[2]	325[3]	354[4]	350[5]	173[6]	276[3]	320[5]	229[4]
Fire Point, °F	200	300	410	420	—	275	—	245

[1]Supercools; freezing point results show variation.
[2]L.T. Setaflash C.C.
[3]H.T. Setaflash C.C.
[4]Pensky-Martin C.C.
[5]Cleveland O.C., no flashpoint observed up to the boiling point using Setaflash closed cup.
[6]Tag C.C.
†These properties are typical of the product, but should not be confused with or regarded as specifications.

(continued)

Table 14.57: (continued)

Properties of Pure Alkanolamines†

Property	Mono-ethanolamine	Diethanol-amine	Triethanolo-amine	Monoisopro-panolamine	Diisopro-panolamine	Triisopro-panolamine
Chemical Name	**2-amino-ethanol**	**2,2'-iminobis-ethanol**	**2,2',2''-nitrilo-trisethanol**	**1-aminopro-pan-2-ol**	**1,1'-iminodi-2-propanol**	**1,1',1''-nitrilotri-2-propanol**
CAS Number	141-43-5	111-42-2	102-71-6	78-96-6	110-97-4	122-20-3
Formula	$HOC_2H_4NH_2$	$(HOC_2H_4)_2NH$	$(HOC_2H_4)_3N$	$HOC_3H_6NH_2$	$(HOC_3H_6)_2NH$	$(HOC_3H_6)_3N$
Molecular Weight	61.09	105.14	149.19	75.11	133.19	191.27
Boiling point, °C 760mm Hg	171	268	340	159	249	306
Freezing point, °C	10	28	21	3.0	44	44
Density, gm/ml, 20°C	1.0147	—	—	0.961	0.999 (30°C)	—
25°C	1.0108	—	1.1196	0.957	0.992 (40°C)	—
40°C	0.9989	1.0828	1.1116	0.944	0.977 (60°C)	1.010
Viscosity, cps, 20°C	24.14	—	—	30.6	—	—
25°C	18.95	—	613.6	17.3 (30°C)	870 (30°C)	—
40°C	10.06	196.4	208.1	6.0 (54°C)	86 (54°C)	100 (60°C)
Refractive index, N_d, 20°C	1.4541	—	1.4835 (25°C)	1.4479	1.4595 (30°C)	1.4560 (25°C)
40°C	1.4474	1.4720	1.4798	1.4369 (50°C)	—	1.4600
Specific heat, 30°C, cal/gm/°C	0.644	0.593	0.555	0.650	0.710 (50°C)	0.635 (50°C)
Flash point, °F[1]	201	325	350	173	276	320
Heat of fusion, btu/lb[2]	144.35	102.75	78.41	77.65	85.14	51.10
Heat of vaporization, btu/lb, 1 atm.[2]	360	287[3]	176	273	188	143
Critical temperature, °C[2]	341.3	442.1	514.3	339.5	399.2	444.9
Critical pressure, atmospheres[2]	44.1	32.3	24.2	55.9	36.0	26.6
Constants for Antoine equation A	8.27771	8.14949	8.36007	7.65791	7.52712	7.65342
B	2103.36	2336.03	2987.63	1666.511	1885.092	2177.51
C	219.339	175.008	205.111	180.077	156.432	150.00

[1]Reference data and methods for Dow Commercial Alkanolamines above.
[2]Calculated.
[3]At 165.5°C and 13.2mm Hg.
†These properties are typical of the product, but should not be confused with or regarded as specifications.

Solubility of Alkanolamines

	Grams of Alkanolamine per 100 grams of solvent at 25°C							
	Mono-ethanol-amine	**Di-ethanol-amine**	**Tri-ethanol-amine 85**	**Tri-ethanol-amine 99**	**Mono-isopropanol-amine**	**Diisopro-panol-amine**	**Tri-isopropanol-amine**	**Isopro-panolamine Mixture**
†Acetone	CM	CM	CM	CM	CM	810	450	CM
Benzene	about 1.2	about 0.2	about 2.7	about 4.9	CM	53	410	CM
n-Butyl Alcohol	CM	CM	CM	CM	CM	200	445	CM
†Carbon Tetrachloride	*	*	*	*	about 4*	about 35*	about 170*	CM*
Dibutyl Phthalate	about 3.6	about 0.5	about 2.8	about 3.8	about 19*	about 5*	about 115*	CM* (slow)
†o-Dichloro-benzene	about 0.7*	about 0.1*	about 6*	CM*	CM*	about 29*	about 300*	CM*
†DOWANOL** EB glycol ether	CM	CM	CM	CM	CM	91	250	CM
†DOWANOL TPM glycol ether	CM	CM	CM	CM	CM	45	18	CM
Ethyl Alcohol (absolute)	CM	CM	CM	CM	CM	430	>500	CM
Ethyl Ether	about 2.2	about 0.7	about 1.5	about 1.8	CM (slow)	9	365	CM (slow)
†Ethylene Dichloride	CM*	IM*	CM*	CM*	CM*	about 150*	about 375*	CM*
†Ethylene Glycol	CM	CM	CM	CM	CM	260	425	CM
†Glycerine	CM	CM	CM	CM	CM	220	115	CM
n-Heptane	about 0.06	about 0.01	about 0.02	about 0.03	0.4	0.1	3.45	0.9
Isopropanol	CM	CM	CM	CM	CM	320	>500	CM
Kerosene	about 0.05	about 0.01	about 0.02	about 0.03	0.4	0.2	4	0.8
Methanol	CM	CM	CM	CM	CM	670	>500	CM
†1,1,1-Trichloro-ethane	about 0.6*	about 0.08*	about 1.4*	about 2.5*	CM*	about 15*	about 280*	CM*
†Methylene Chloride	CM*	IM*	CM*	CM*	CM*	about 180*	>500*	CM*

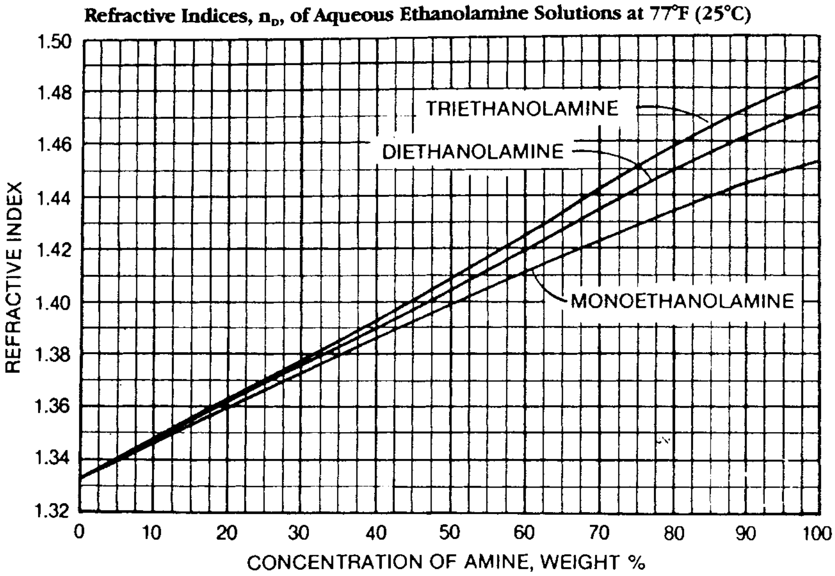
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Table 14.57: (continued)

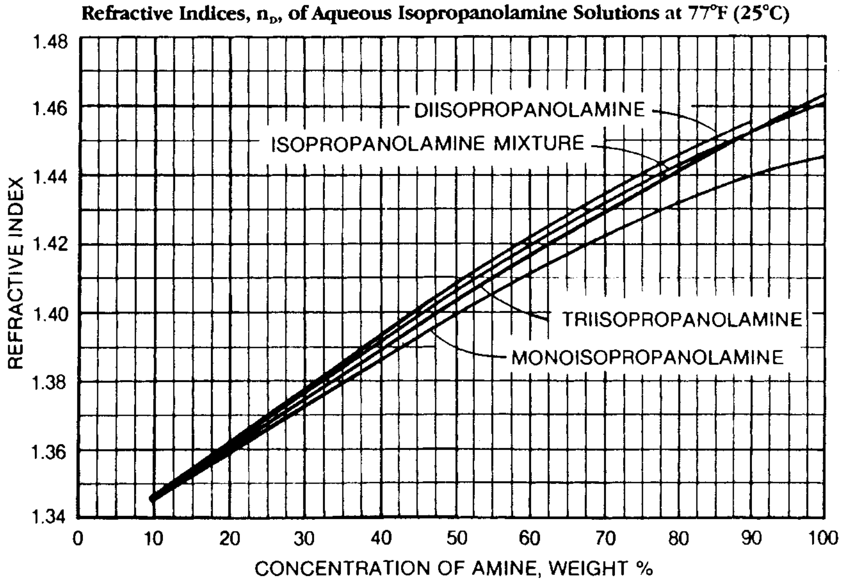
	Grams of Alkanolamine per 100 grams of solvent at 25°C							
	Mono-ethanol-amine	Di-ethanol-amine	Tri-ethanol-amine 85	Tri-ethanol-amine 99	Mono-isopropanol-amine	Diisopro-penol-amine	Tri-isopropanol-amine	Isopro-panolamine Mixture
Mineral Oil	about 0.06	about 0.02	about 0.03	about 0.03	0.2	0.05	about 0.4	0.2
Mineral Spirits ...	about 0.08	about 0.01	about 0.03	about 0.04	0.4	0.2	5	1.0
Naphtha VMP....	about 0.07	about 0.01	about 0.03	about 0.06	0.4	0.3	6	1.6
†Perchloro-ethylene.......	about 0.1*	about 0.02*	about 0.1*	about 0.17*	about 0.7*	about 0.9*	about 160*	CM*
Pine Oil.........	CM	CM	CM	CM	CM	110	90	CM
Toluene.........	about 0.7	about 0.1	about 0.6	about 1.7	CM	12	340	CM
Water...........	CM	CM	CM	CM	CM	1200	>500	CM

CM = completely miscible IM = not completely miscible †Dow Solvents
*The amine reacts with the solvent to some extent
**Trademark of The Dow Chemical Company

Refractive Indices, n_D, of Aqueous Ethanolamine Solutions at 77°F (25°C)



Refractive Indices, n_D, of Aqueous Isopropanolamine Solutions at 77°F (25°C)

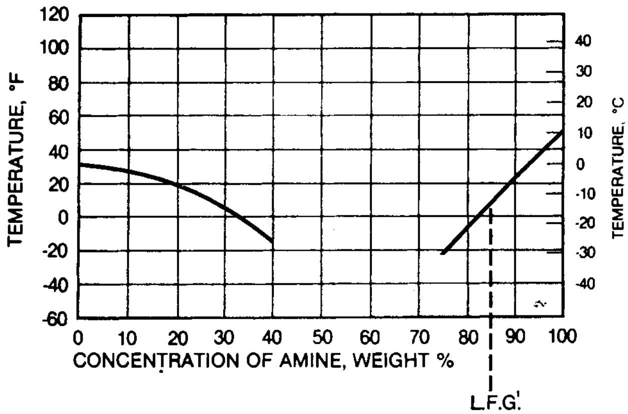


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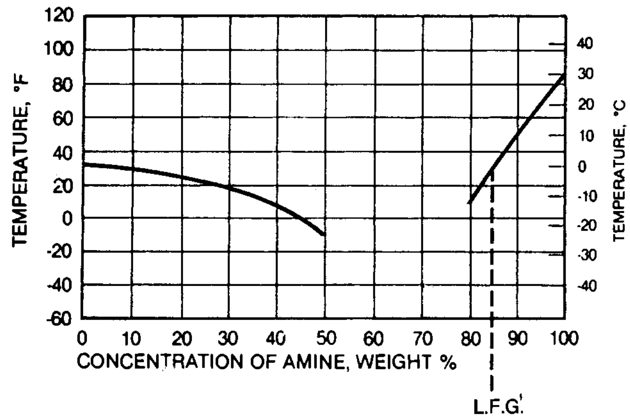
Table 14.57: (continued)

Freezing Curves of Aqueous Ethanolamine Solutions

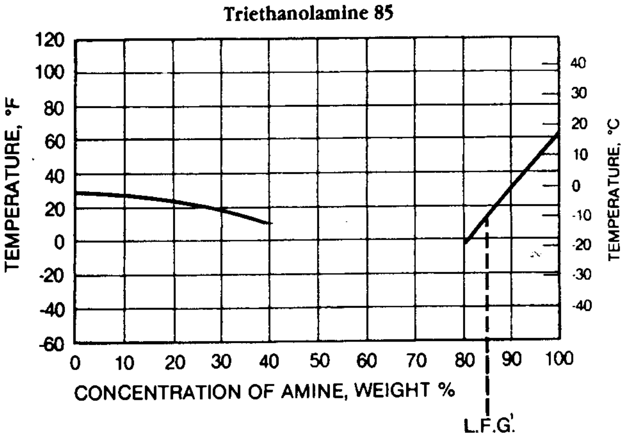
Monoethanolamine



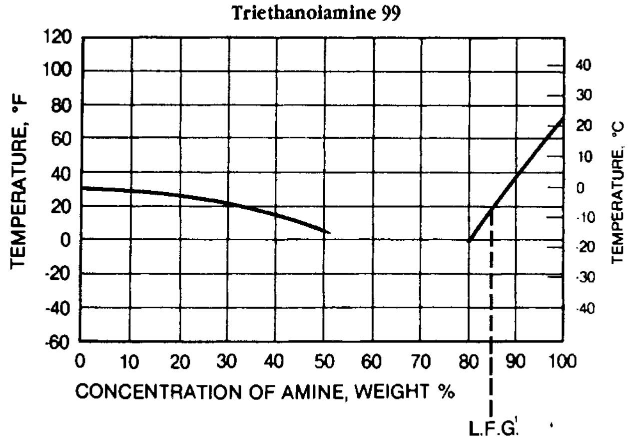
Diethanolamine



Triethanolamine 85

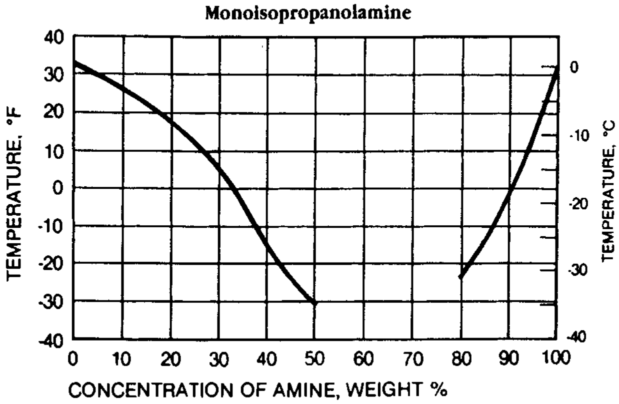


Triethanolamine 99

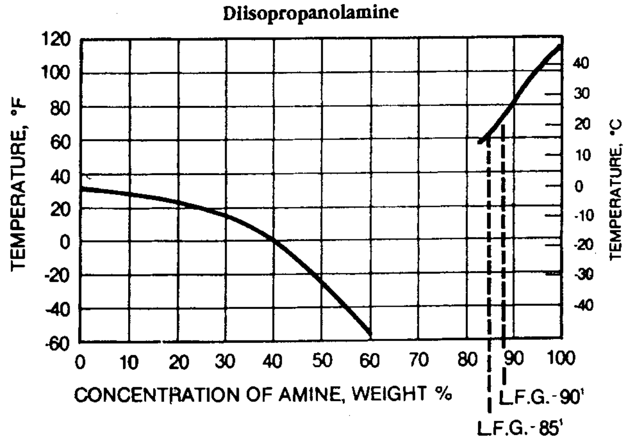


Freezing Curves of Aqueous Isopropanolamine Solutions

Monoisopropanolamine



Diisopropanolamine

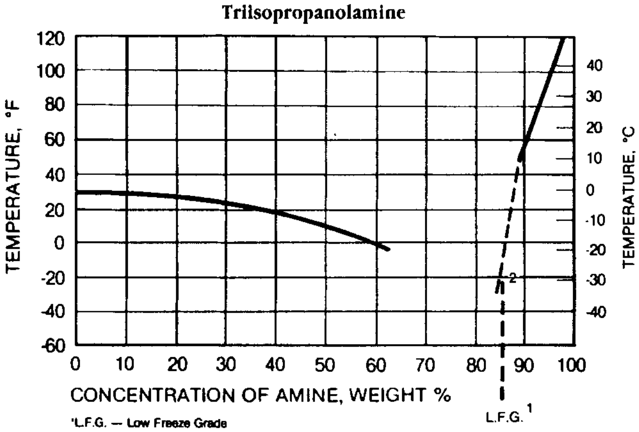


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Table 14.57: (continued)

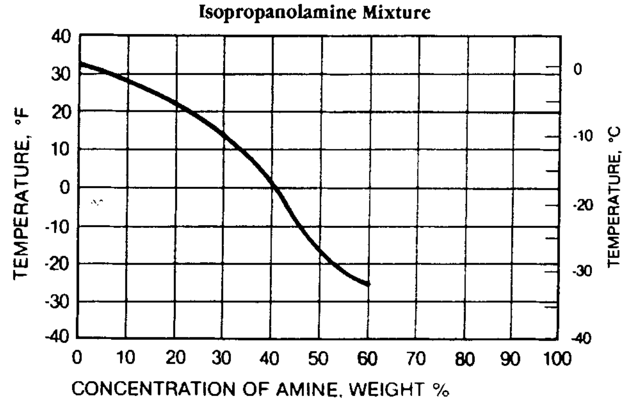
Freezing Curves of Aqueous Isopropanolamine Solutions (Con't.)

Triisopropanolamine



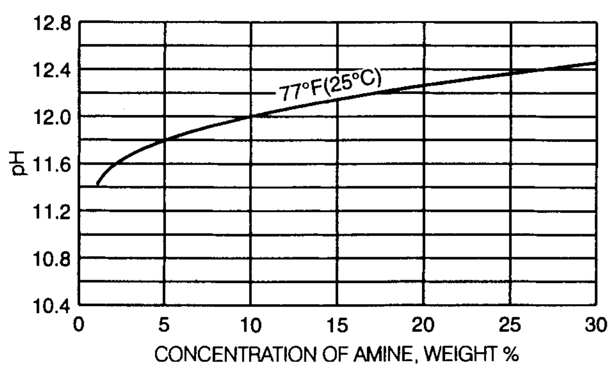
[1]L.F.G. — Low Freeze Grade
[2]Became viscous below this temperature

Isopropanolamine Mixture

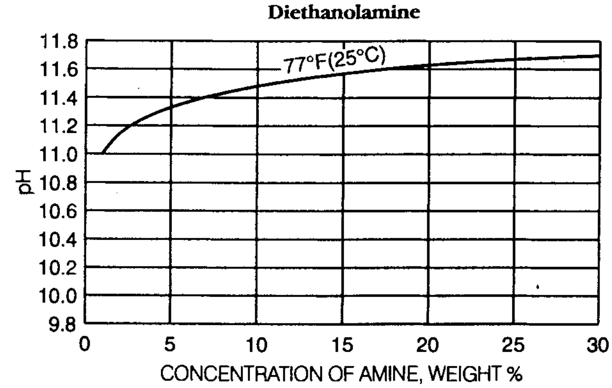


pH Values of Aqueous Ethanolamines

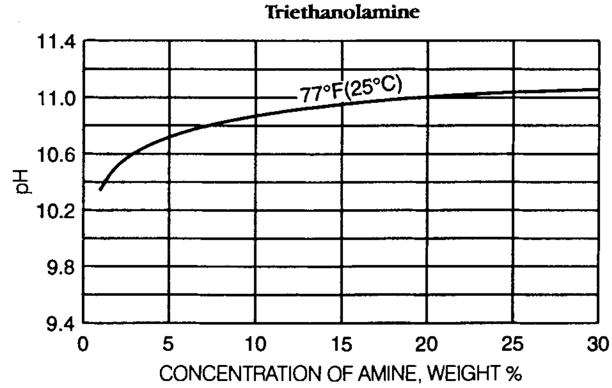
Monoethanolamine



Diethanolamine



Triethanolamine

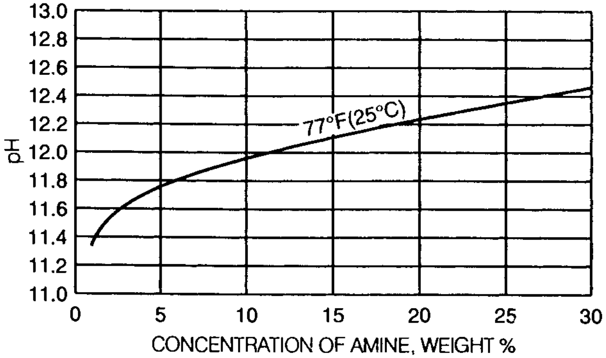


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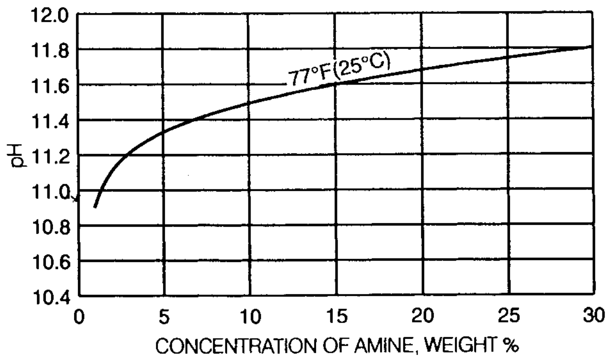
Table 14.57: (continued)

pH Values of Aqueous Isopropanolamines

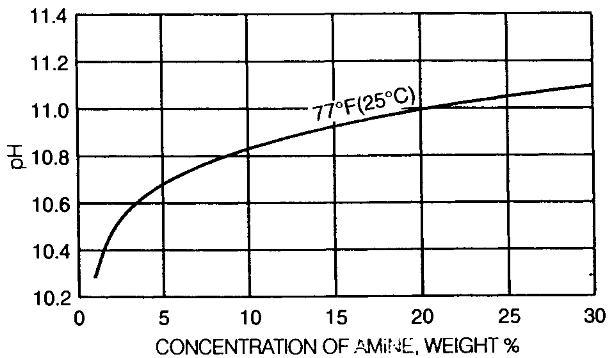
Monoisopropanolamine



Diisopropanolamine

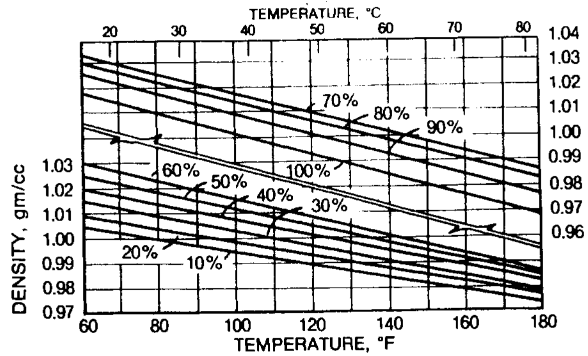


Triisopropanolamine

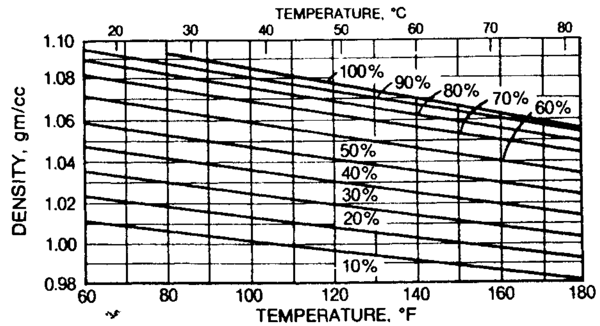


Densities of Aqueous Ethanolamine Solutions (weight % of amine)

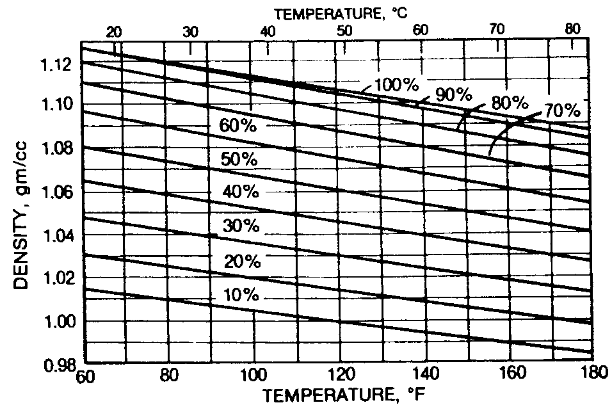
Monoethanolamine



Diethanolamine



Triethanolamine

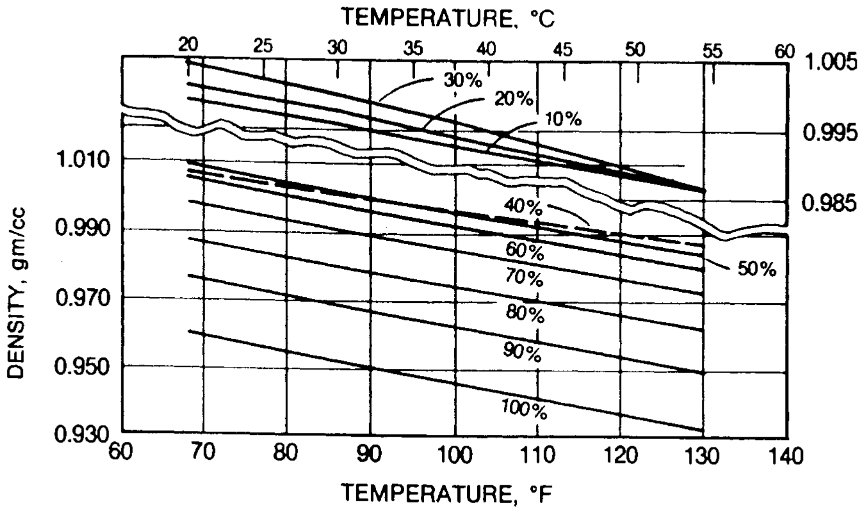


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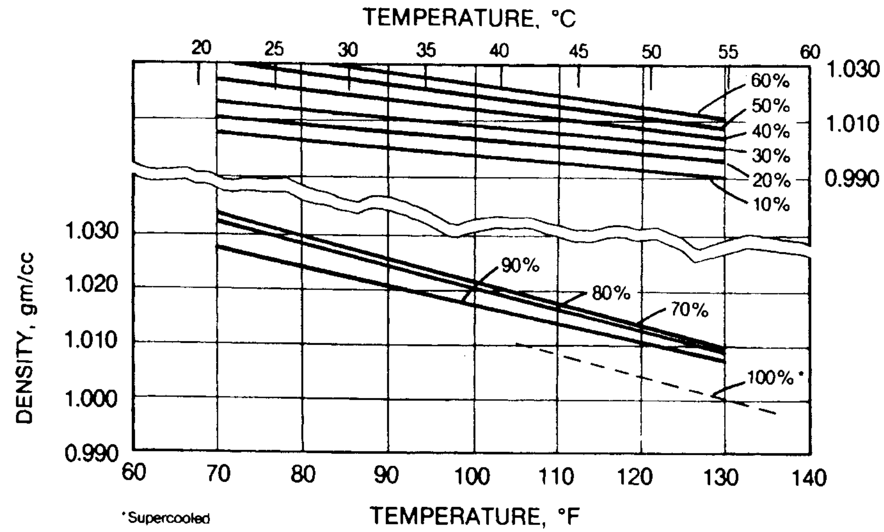
Table 14.57: (continued)

Densities of Aqueous Isopropanolamine Solutions
(weight % of amine)

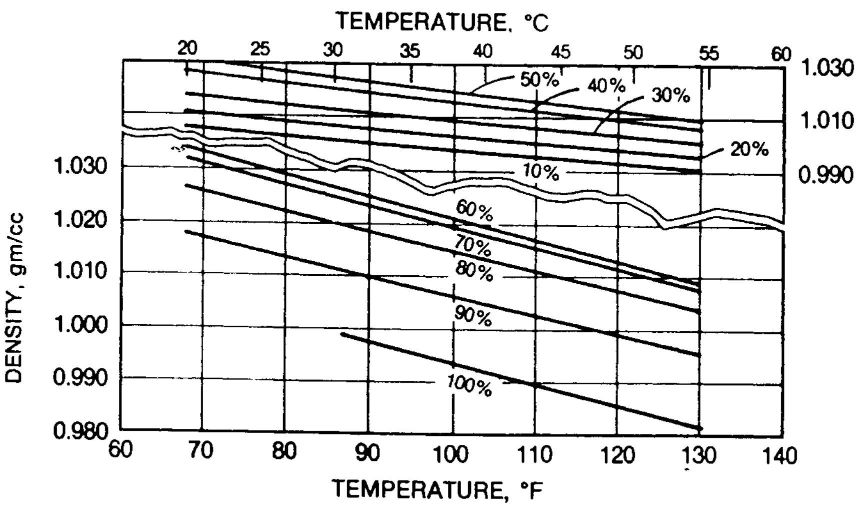
Monoisopropanolamine



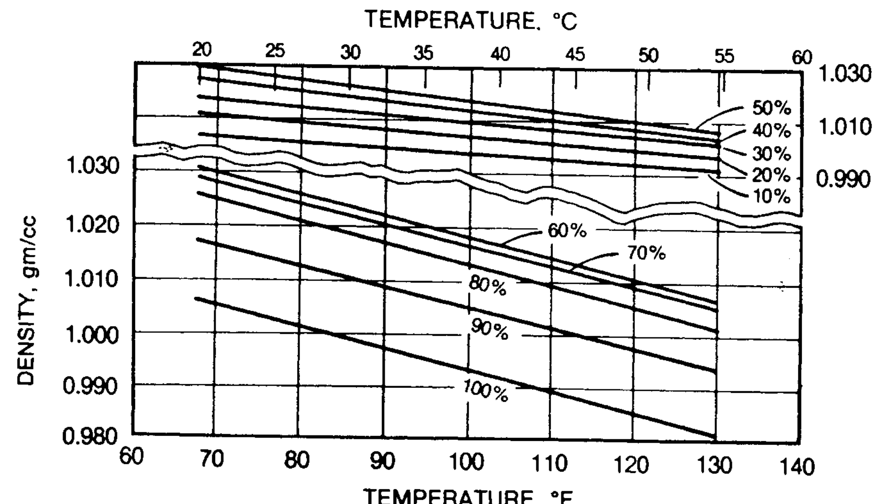
Triisopropanolamine



Diisopropanolamine



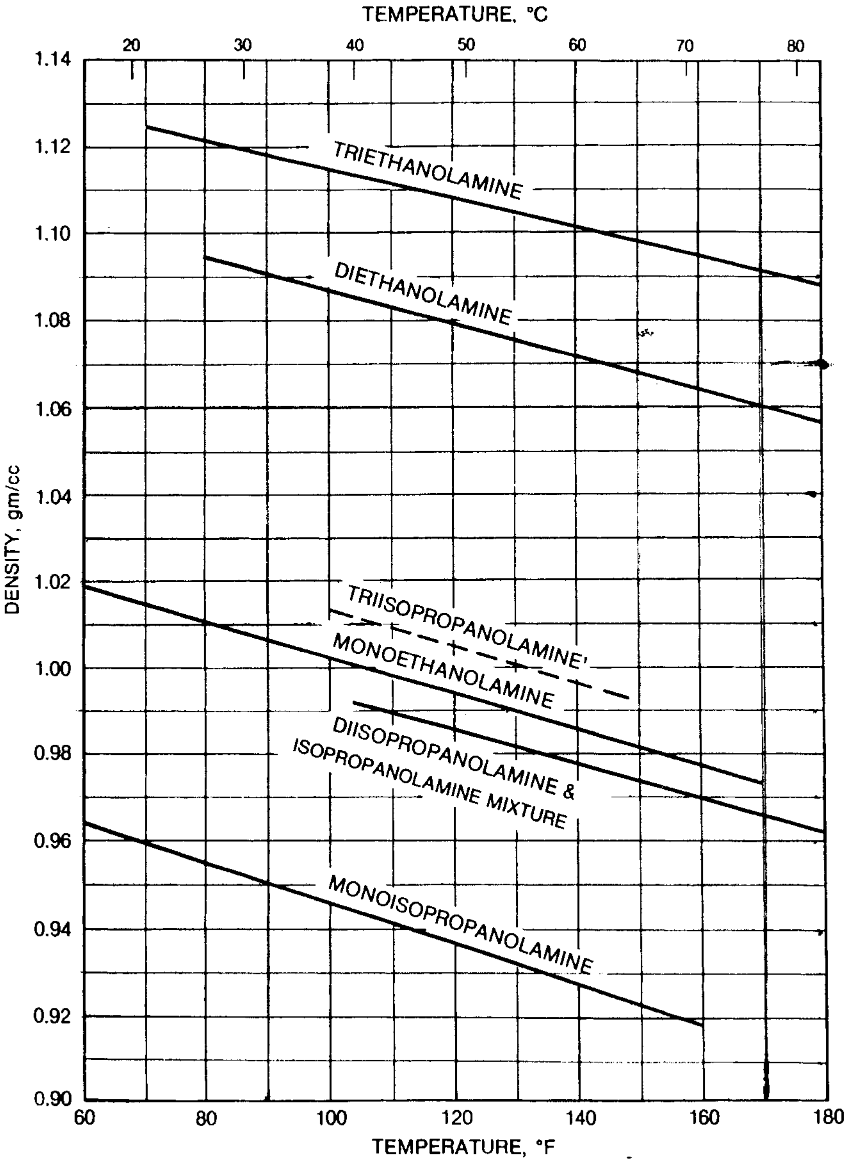
Isopropanolamine Mixture



(continued)

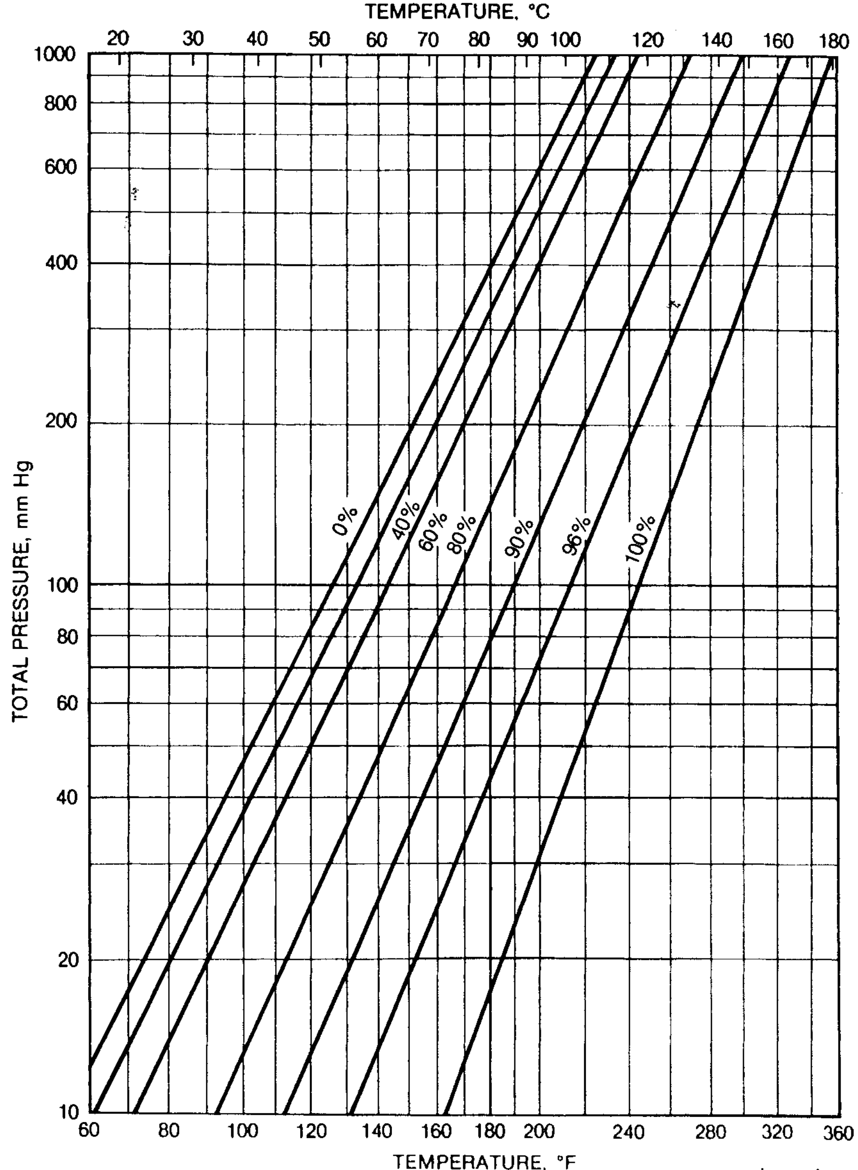
Table 14.57: (continued)

Densities of Alkanolamines



[1]Extrapolation on Supercooled Product

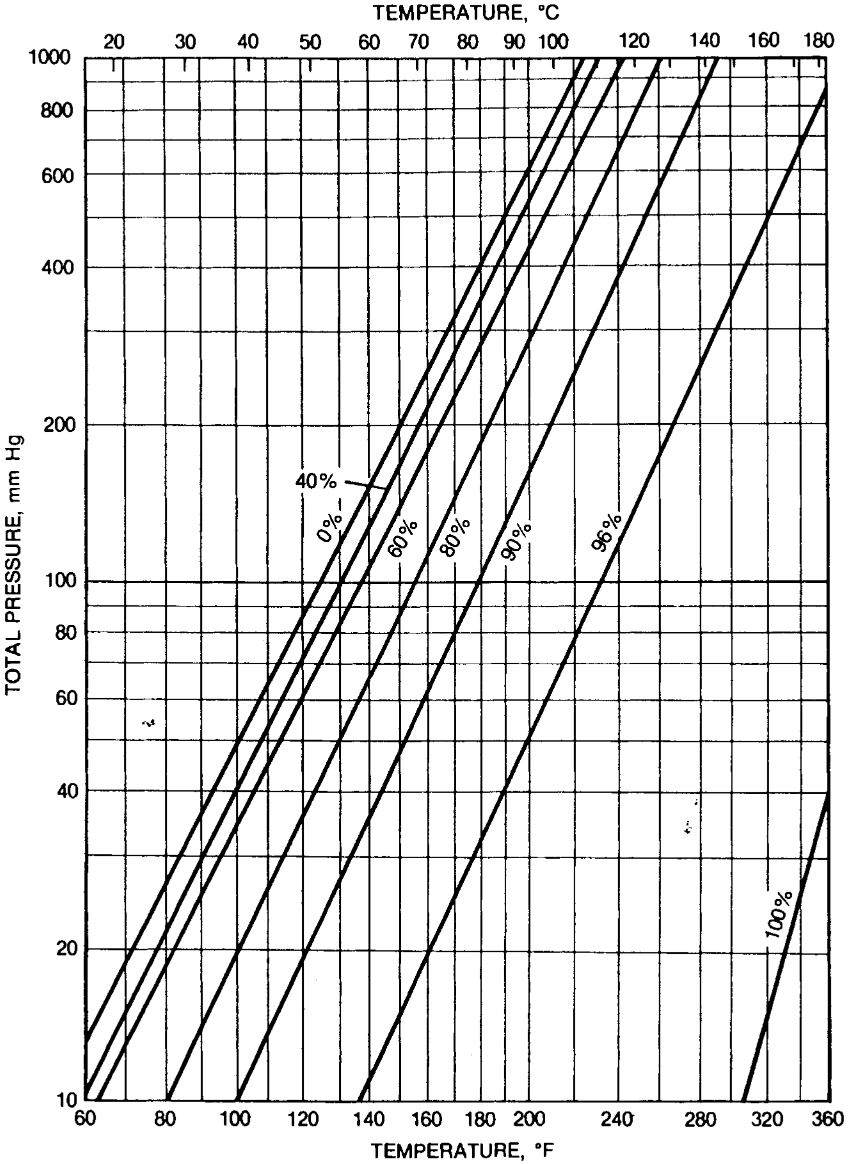
Total Vapor Pressures of Aqueous Monoethanolamine Solutions (weight % of amine)



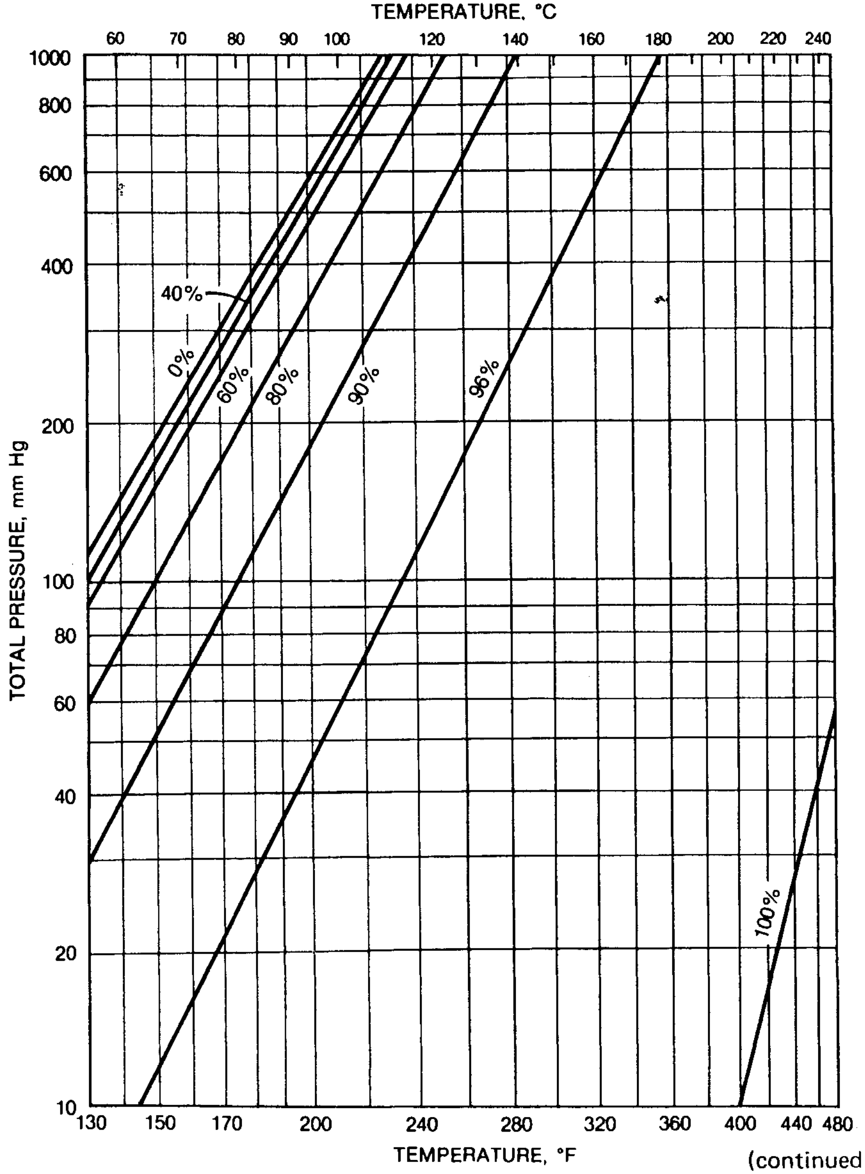
(continued)

Table 14.57: (continued)

Total Vapor Pressures of Aqueous Diethanolamine Solutions
(weight % of amine)



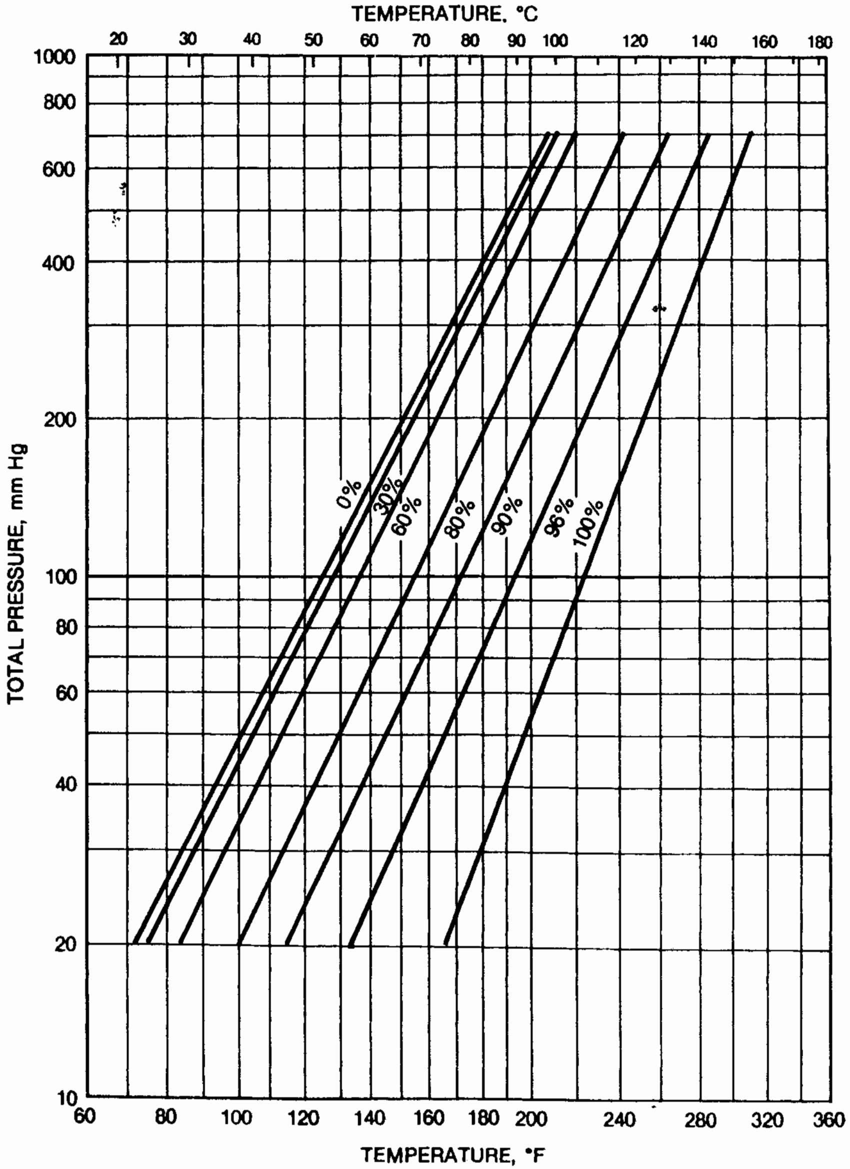
Total Vapor Pressures of Aqueous Triethanolamine Solutions
(weight % of amine)



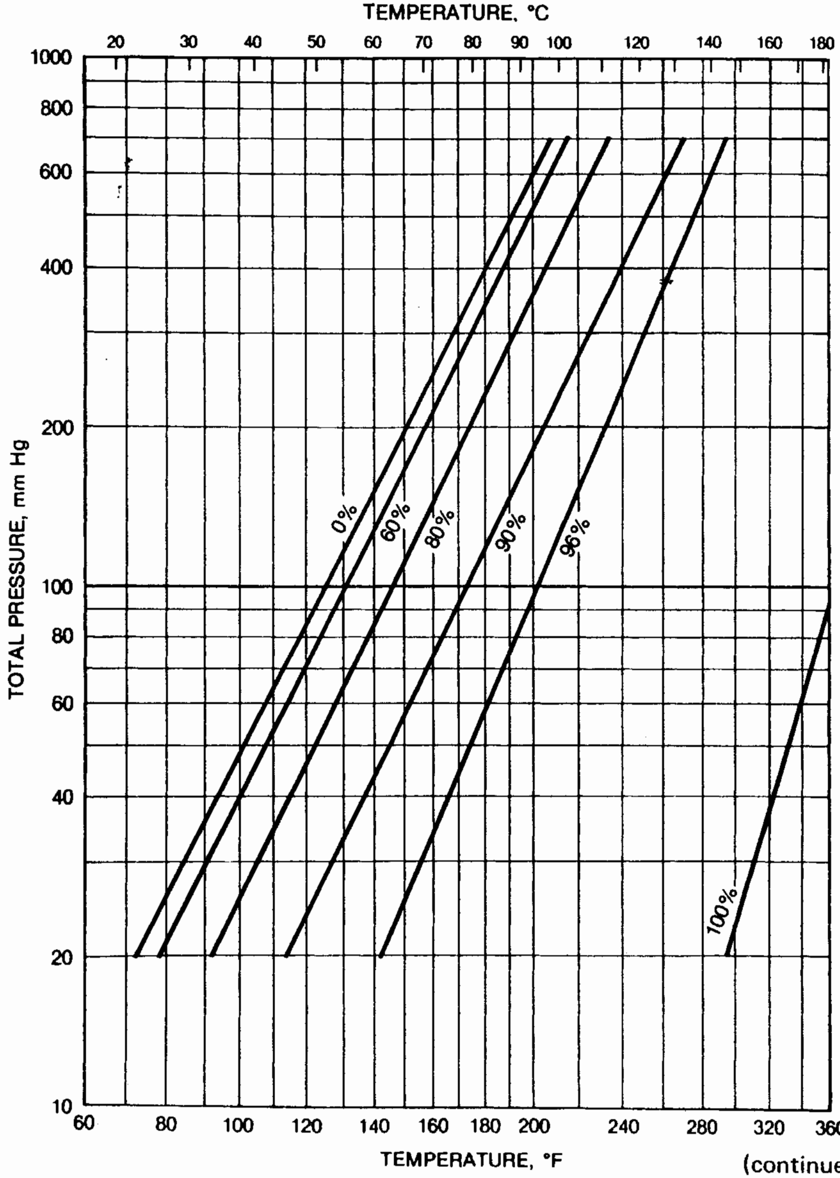
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Table 14.57: (continued)

Total Vapor Pressures of Aqueous Monoisopropanolamine Solutions (weight % of amine)



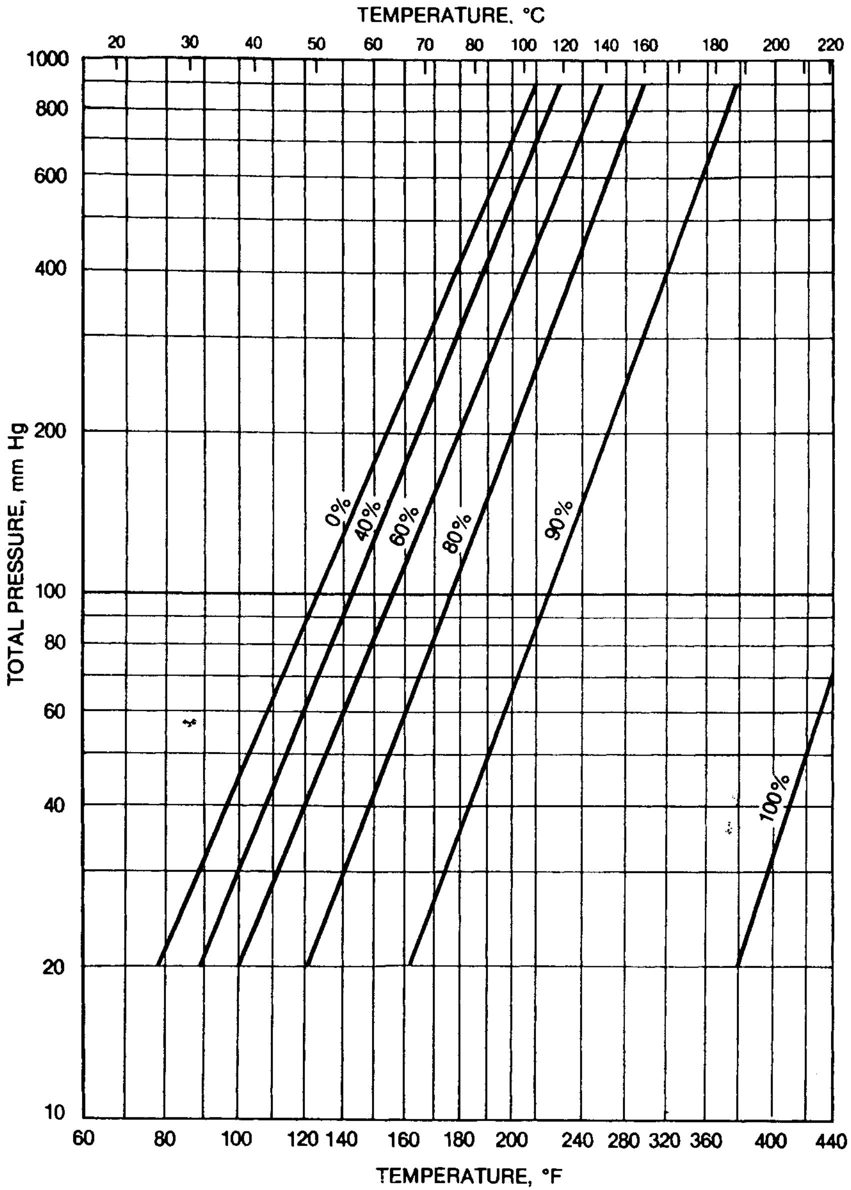
Total Vapor Pressures of Aqueous Diisopropanolamine Solutions (weight % of amine)



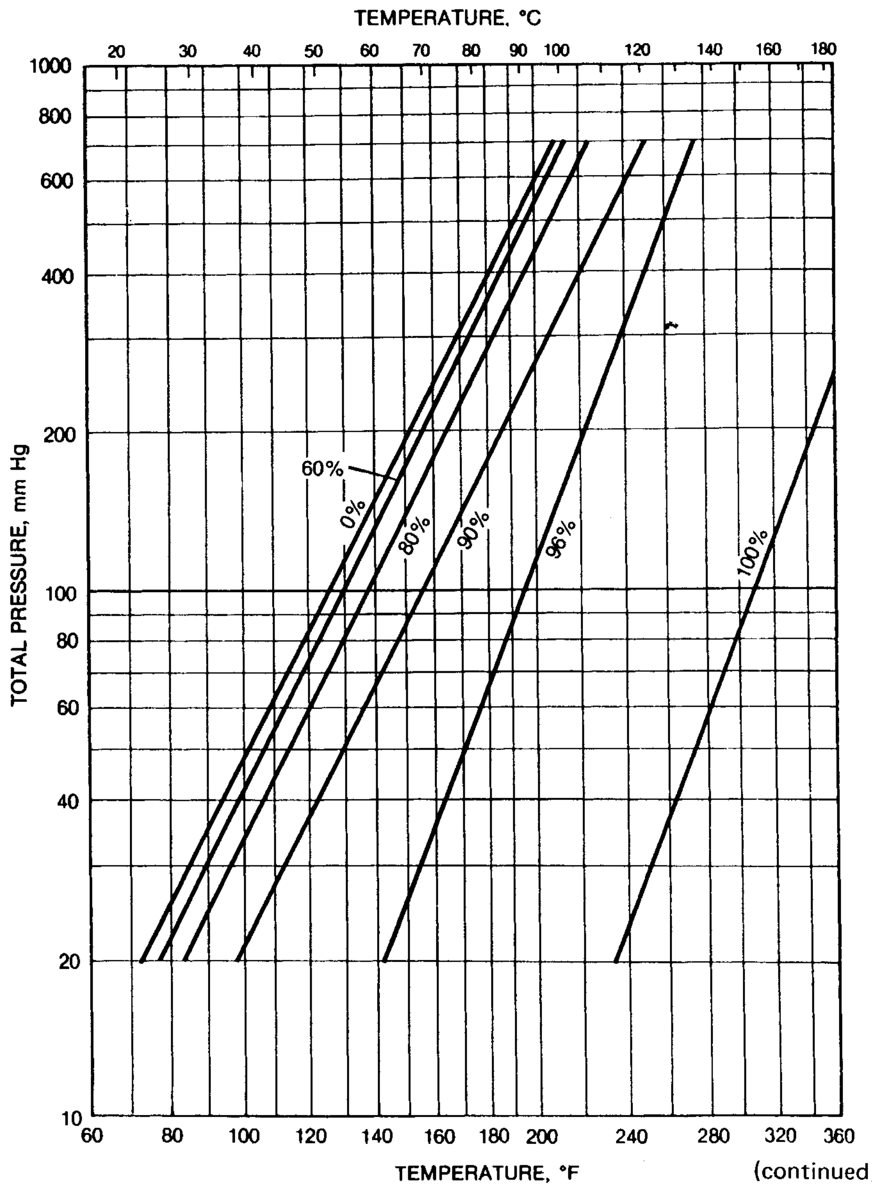
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Table 14.57: (continued)

Total Vapor Pressure of Aqueous Triisopropanolamine Solutions (weight % of amine)



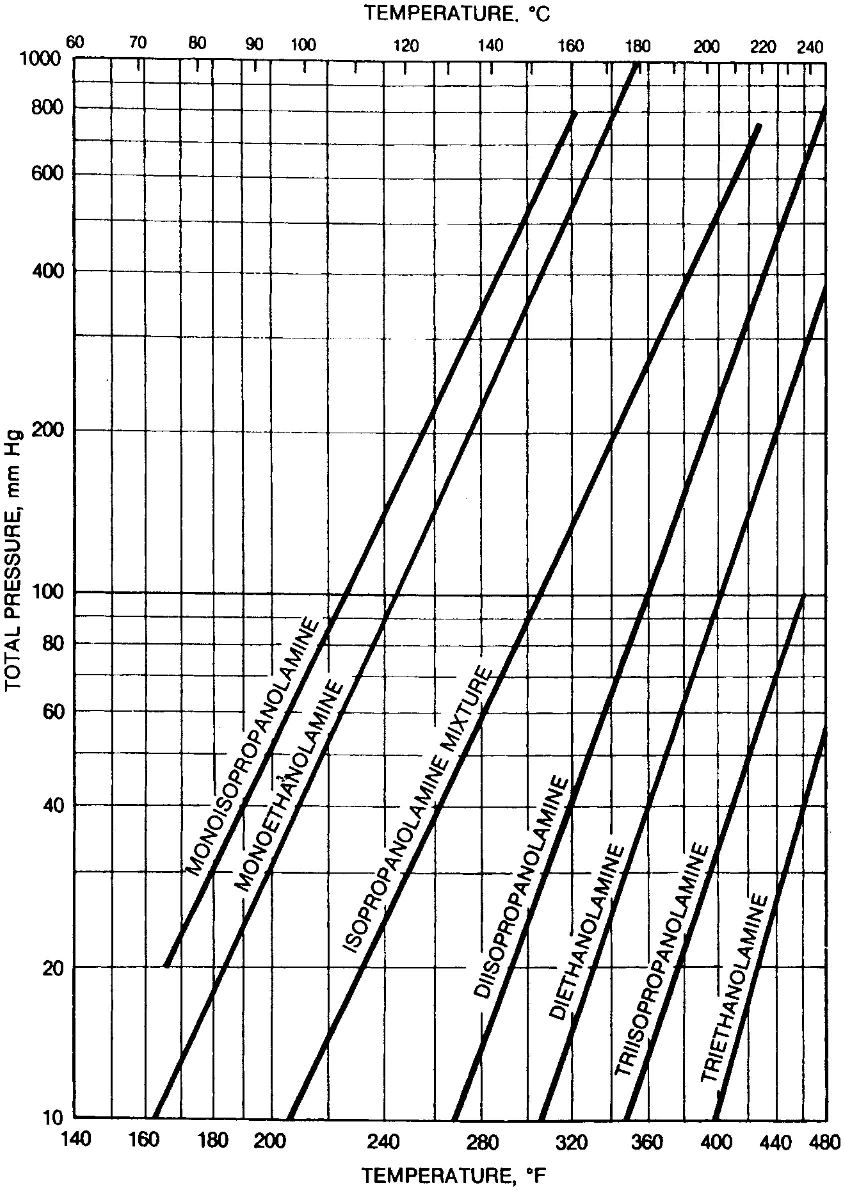
Total Vapor Pressures of Aqueous Isopropanolamine Mixture Solutions (weight % of amine)



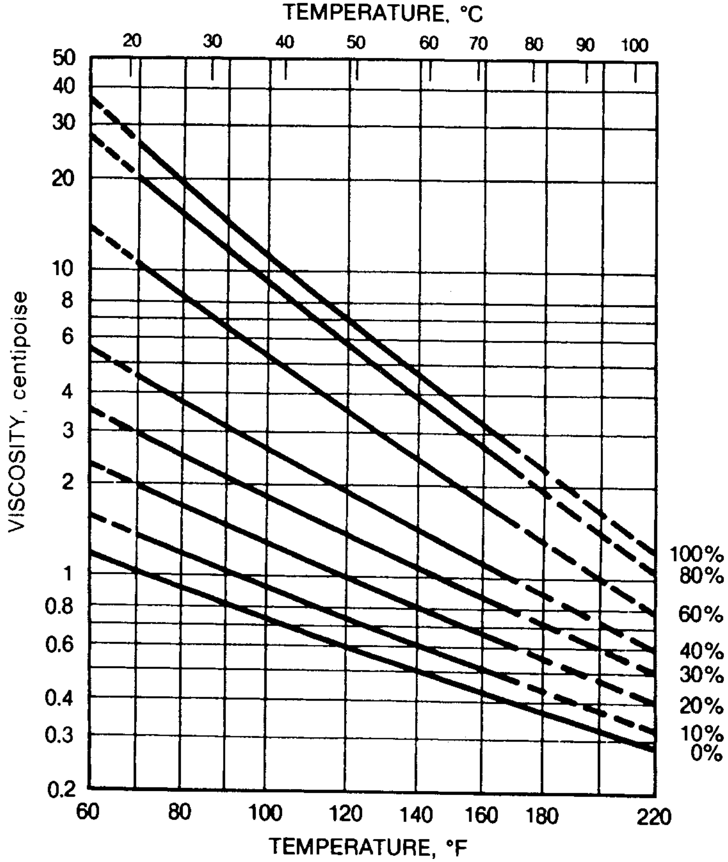
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Table 14.57: (continued)

Total Vapor Pressures of Alkanolamines



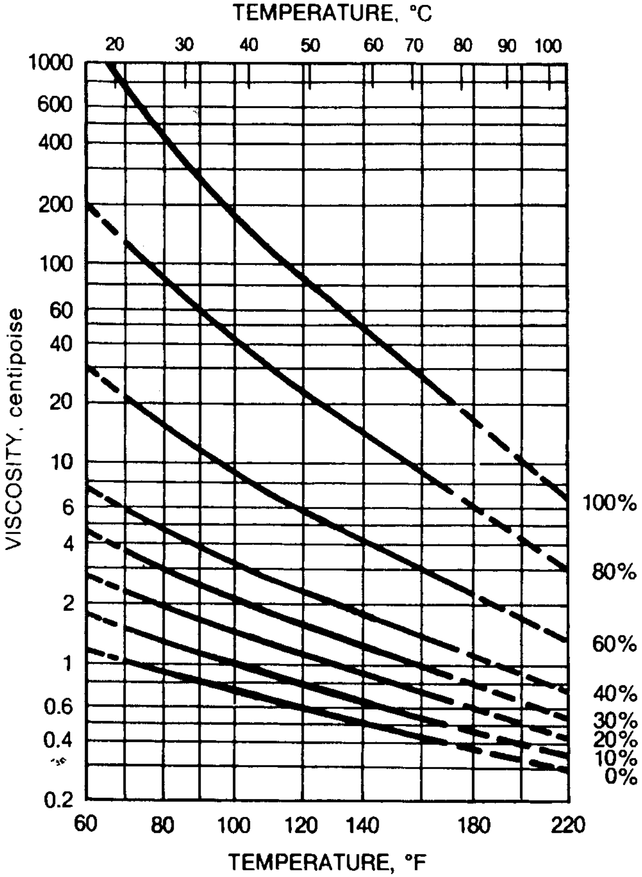
Viscosities of Aqueous Monoethanolamine Solutions (weight % of amine)



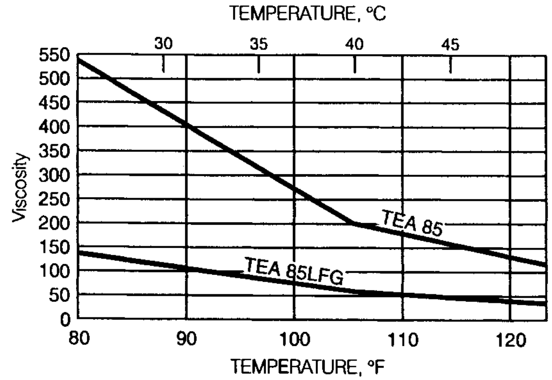
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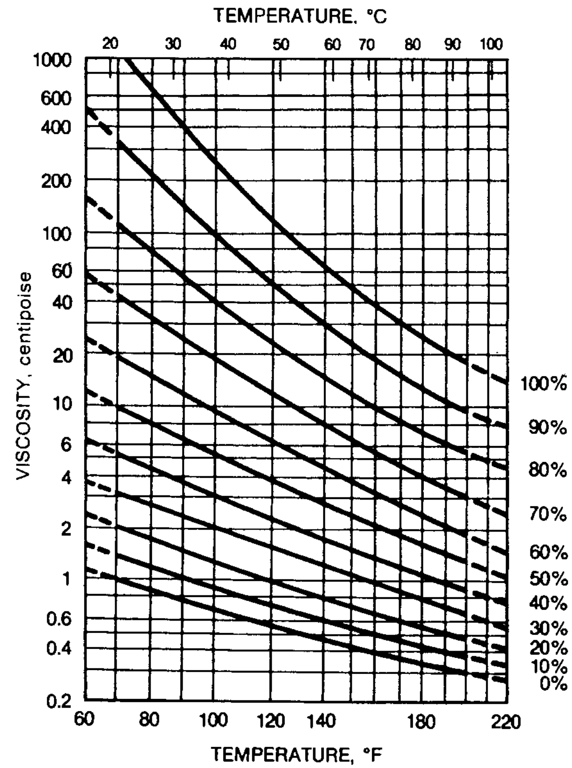
Table 14.57: (continued)

Viscosities of Aqueous Diethanolamine Solutions
(weight % of amine)



Viscosities of Aqueous Triethanolamine Solutions
(weight % of amine)

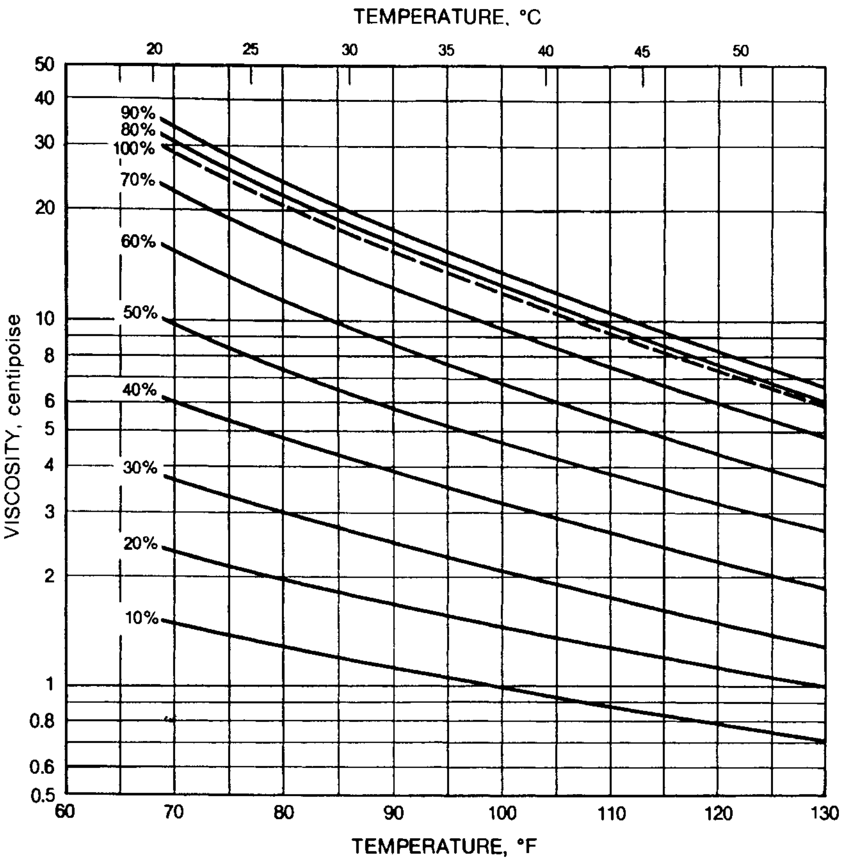




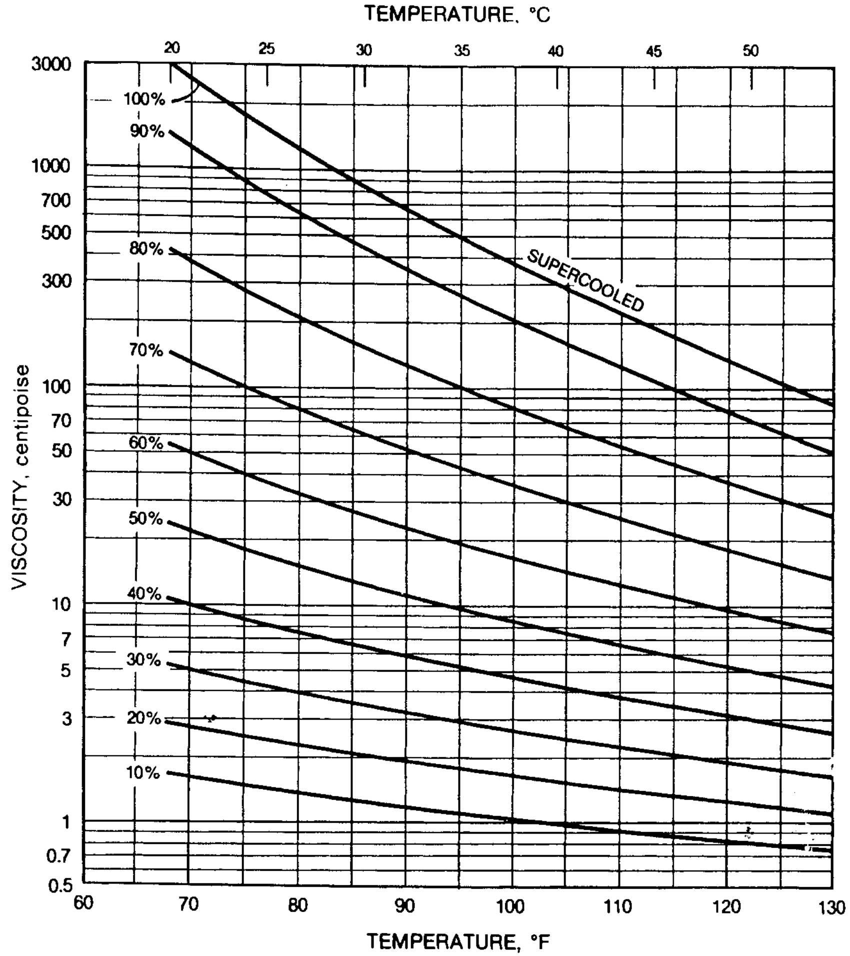
(continued)

Table 14.57: (continued)

Viscosities of Aqueous Monoisopropanolamine Solutions (weight % of amine)



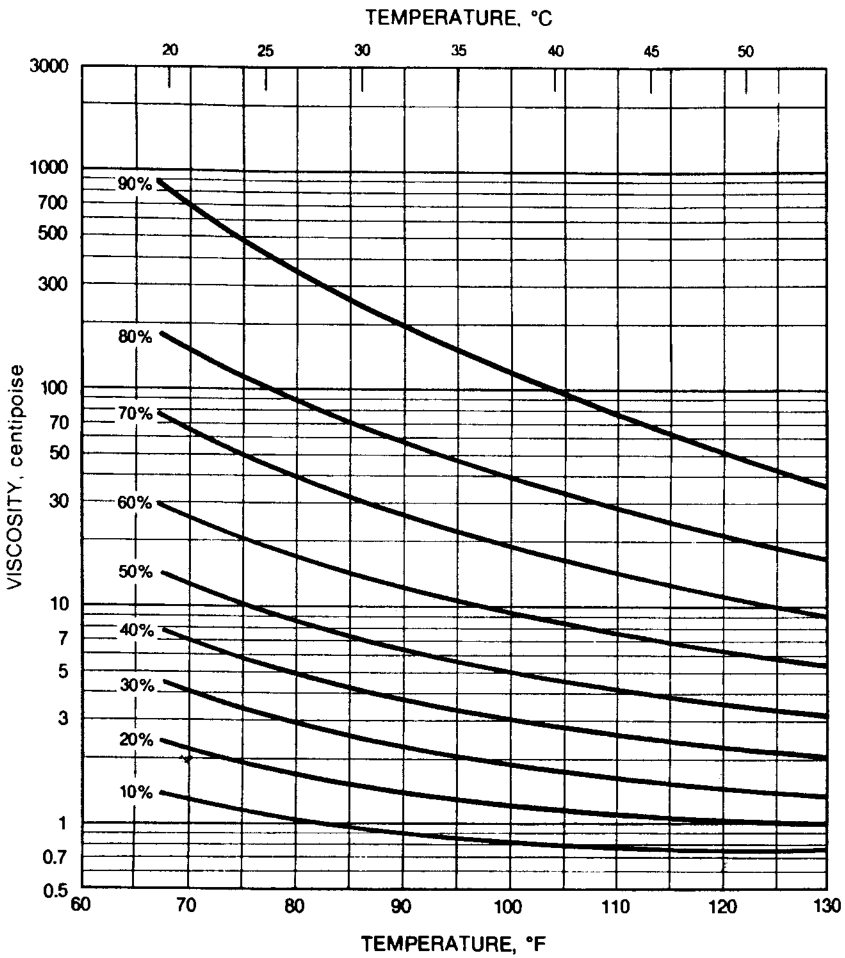
Viscosities of Aqueous Diisopropanolamine Solutions (weight % of amine)



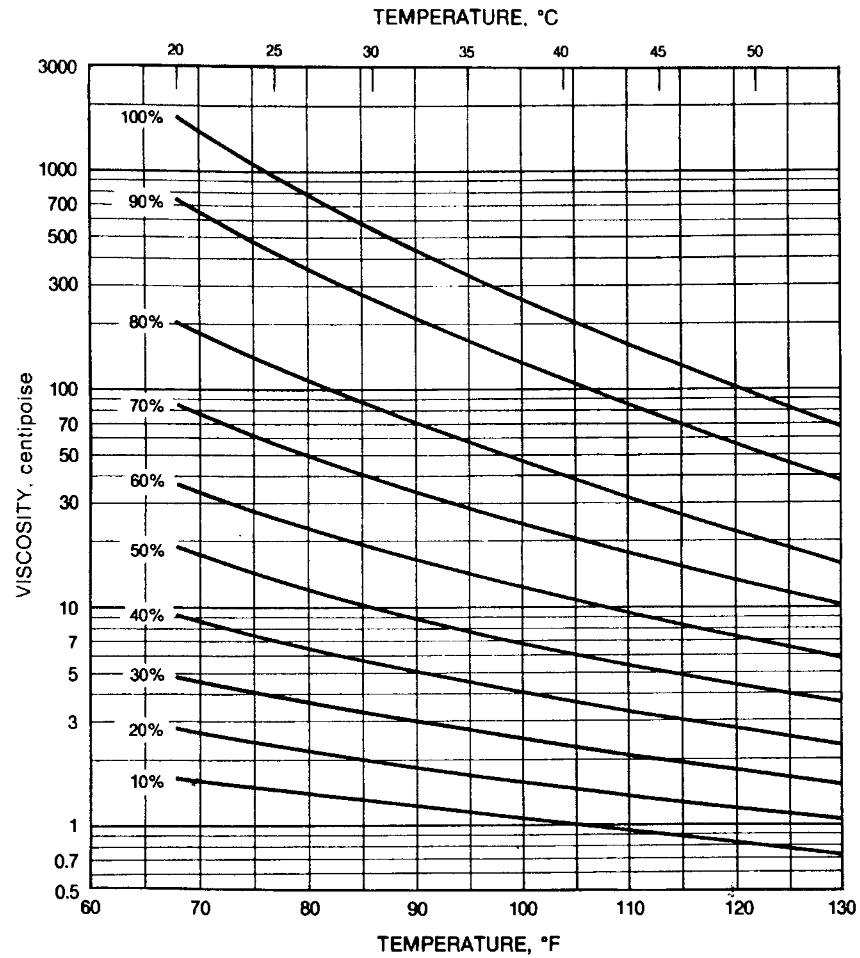
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Table 14.57: (continued)

Viscosities of Aqueous Triisopropanolamine Solutions (weight % of amine)



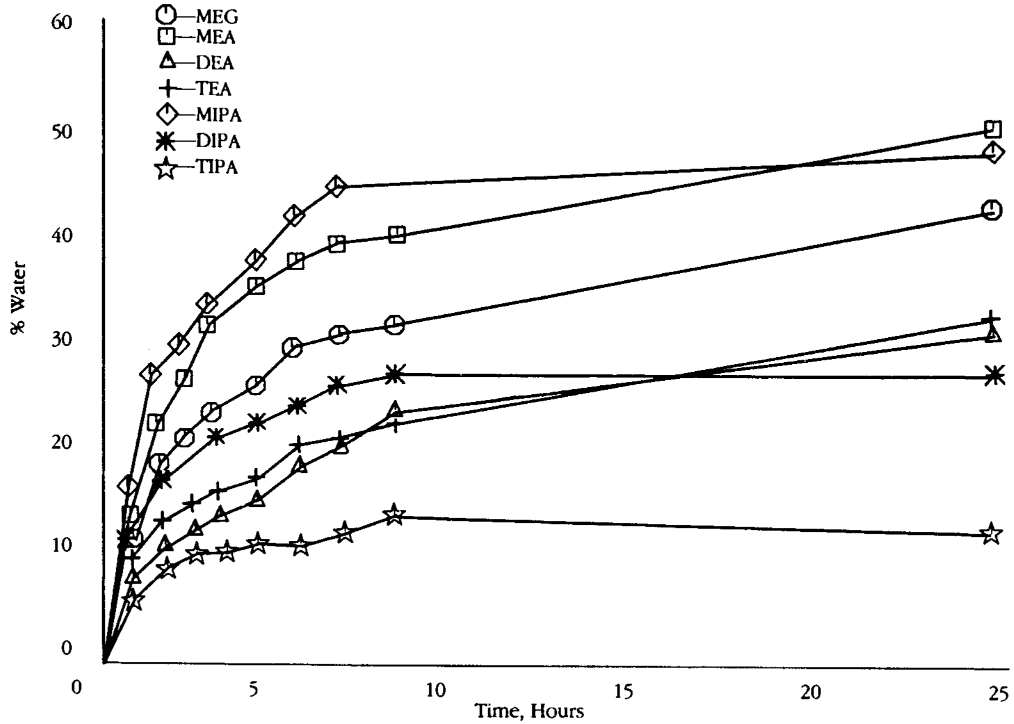
Viscosities of Aqueous Isopropanolamine Mixture Solutions (weight % of amine)



(continued)

Table 14.57: (continued)

Hygroscopicity
(Water Uptake)
MEG[1] vs ALKANOLAMINES
45°C/74% Relative Humidity



Time	MEG	MEA	DEA	TEA	MIPA	DIPA	TIPA
0	0.2	0.1	0.1	0.1	0.1	0.2	0.2
1	12.6	13.3	8.7	10.1	17.4	11.5	6.4
2	19.3	22.1	11.2	13.4	26.0	15.6	9.2
3	22.3	27.2	13.5	15.6	29.5	18.7	10.5
4	25.8	31.8	15.3	16.8	33.2	20.2	10.6
5	29.5	34.9	17.2	18.0	37.4	22.5	11.3
6	30.5	37.9	19.1	20.2	41.2	23.4	11.3
7	32.5	39.8	21.3	20.9	43.5	24.9	12.1
8	33.2	41.0	22.5	21.5	42.7	25.5	12.9
24	42.3	49.7	31.4	31.3	48.7	28.1	11.4

[1]MEG is monoethylene glycol

Table 14.58: Humko Amines *(26)*

Primary Amines

Product	Description *(CTFA adopted name)*	% Primary Min	Total amine value Min	Color Gardner, 1963 Max	% H_2O Max	Iodine value	Typical carbon chain composition: Saturated C_{10}	C_{12}	C_{14}	C_{16}	C_{18}	Unsaturated $C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Kemamine P-650D	Distilled Coco	97	270	1	0.5	12 Max	2	58	20	10	5	5		
Kemamine P-970*	Technical Hydrogenated Tallow *(Hydrogenated Tallow Amine)*	93	205	3	0.5	3 Max			4	29	67			
Kemamine P-970D*	Distilled Hydrogenated Tallow *(Hydrogenated Tallow Amine)*	97	210	1	0.5	3 Max			4	29	67			
Kemamine P-974D	Distilled Tallow *(Tallow Amine)*	97	210	1	0.5	38 Min			4	29	25	38	4	
Kemamine P-989D	Distilled Oleyl *(Oleamine)*	97	205	1	0.5	70 Min			4	14	10	65	7	
Kemamine P-999	Technical Oleic-Linoleic	93	200	5	0.5	85 Min				15	6	52	25	2

*Available in flake form.

1,3-Propylenediamine

Product	Description	% Diamine	Amine values: 1°	2°	3°	Total	Color Gardner, 1963 Max	% H_2O Max	Iodine value
Kemamine D-190	N-90% Behenyl-Arachidyl	88 Typ	150 Typ	120 Typ	10 Typ	280 Min	9	0.5	10 Max
Kemamine D-999	N-Oleic-Linoleic	88 Typ	150 Min	140 Min	10 Max	300 Min	8	0.5	70 Min

Tertiary Amines

Product	Description *(CTFA adopted name)*	% Tertiary Min	Total amine value Min	Color Gardner, 1963 Max	% H_2O Max	Typical carbon chain composition: Saturated C_{10}	C_{12}	C_{14}	C_{16}	C_{18}	Unsaturated $C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Kemamine T-6502D	Distilled Dimethyl Coco	95	230	1	0.5	2	61	22	8	3	2		
Kemamine T-9701	Methyl Di-Hydrogenated Tallow	95	103	3	0.5			4	29	67			
Kemamine T-9892D	Distilled Dimethyl Oleyl	95	180	1	0.5			4	14	10	65	7	
Kemamine T-9902D	Distilled Dimethyl Stearyl Dimethyl Stearamine	95	180	1	0.5				10	90			
Kemamine T-9992D	Distilled Dimethyl Oleic-Linolenic	95	180	2	0.5				15	7	53	22	3

Dimer Amines

Product	Description	Total amine value Min	Primary amine value Min	Secondary amine value Min	Color Gardner, 1963 Max	% Moisture
Kemamine DP-3695*	Dimer Diprimary Amine	185	175		14	1 Max
Kemamine DP-3680*	Dimer Diprimary Amine	175	165		14	1 Max
Kemamine DD-3680*	Dimer Diamine	280	135	135	14	1 Max

*Semicommercial.

Table 14.59: Proctor & Gamble Tertiary Amines *(39)*

Chemical Properties	AT-1295	AT-1495	AT-1695	AT-1214	AT-121416
% Total Amine	97.3 min (98.5)	97.3 min (98.4)	97.3 min (98.2)	97.3 min (98.4)	97.3 min (98.4)
% Non-Terminal Amine	6.0 max (5.2)	6.0 max (5.0)	6.0 max (5.6)	6.0 max (5.1)	6.0 max (5.0)
% Non-Amine Material	2.0 max (1.5)	2.0 max (1.5)	2.0 max (1.7)	2.0 max (1.5)	2.0 max (1.5)
Amine Value	254-264 (263)	226-234 (232)	203-211 (208)	246-254 (252)	236-244 (243)
% Moisture	0.20 max (0.1)	0.20 max (0.1)	0.20 max (0.1)	0.2 max (0.1)	0.2 max (0.1)
Physical Properties					
Color-APHA	35 max (15)	25 max (19)	35 max (29)	35 max (17)	35 max (19)
Appearance	Clear to slight haze	Clear to slight haze	Clear to slight haze	Clear to slight haze	Clear to slight haze
Equivalent Weight	(213)	(242)	(270)	(223)	(231)
Compostion (%GC)					
C10 & Lower	1.0 max (0.0)				1.0 max (0.0)
C12	95.0 min (98.2)	3.0 max (1.0)		69.0+/-1.5 (68.7)	41.5+/-1.5 (41.4)
C14	(1.3)	95.0 min (97.5)	5.0 max (2.2)	31.0+/-1.5 (30.5)	49.0 +/-1.5 (48.9)
C16	2.0 max (0.3)	2.0 max (1.4)	95.0 min (97.4)	1.0 max (0.8)	9.5 +/-1.5 (9.7)
C18 & Higher			1.0 max (0.3)		0.1 max (0.0)
CAS No.	112-18-5	112-75-4	112-69-6	112-18-5 112-75-4	112-18-5 112-75-4 112-69-6

Table 14.60: Occidental Ethanolamines *(27)*

Ethanolamines Products, Grades and Specifications

Specifications	**MEA 99**	**DEA 99**	**TEA 85**	**TEA 97 HC**
Monoethanolamine, wt. %	99.0 min.	1.0 max.	0.5 max.	0.5 max.
Diethanolamine, wt. %	0.5 max.	98.5 min.	15.0 max.	3.0 max.
Triethanolamine, wt. %	-	1.0 max.	85.0 min.	97.0 min.
Color (APHA), max.	15	15	50	250
Apparent equivalent wt.	61.0-62.0	104-106	140-145	145-150
Water, wt. % max.	0.3	0.15	0.2	0.2
Miscellaneous Grades	**PEA 60**	**PEA 85**		
Monoethanolamine, wt. %	5 max.	2 max.		
Diethanolamine, wt. %	40 max.	15 max.		
Triethanolamine, wt. %	60 min.	85 min.		
Ethylene glycol, wt. %	5 max.	2 max.		
Heavy ends & others, wt. %	4 max.	4 max.		
Color (APHA)	1000	1000		
Water, wt. % max.	2	1.5		

Low Freeze Grades

Ethanolamines have relatively high freezing points, and in winter, especially in northern climates, they can become too viscous to pump. For customers in these areas whose applications are not sensitive to water, OxyChem offers each ethanolamine in a "Low Freeze" grade. Low freeze grade ethanolamines are produced by the addition of 15 percent by weight of deionized water. They are blended in the delivery vessels prior to each shipment, and therefore, are not stored as finished products.

Low Freeze Grades	**MEA 99 LFG**	**DEA 99 LFG**	**TEA 85 LFG**	**TEA 97 LFG**
Monoethanolamine, wt. %	84.0 min.	0.9 max.	0.5 max.	0.5 max.
Diethanolamine, wt. %	0.5 max.	83.5 min.	13.0 max.	2.7 max.
Triethanolamine, wt. %	-	0.9 max.	72.0 min.	83.0 min.
Color (APHA), max.	25	25	50	250
Water, wt. % max.	15.5	15.5	15.5	15.5
Freezing point, (°C)	-12	1	-5.5	-5.5

(continued)

Table 14.60: (continued)

Compatibility

Acceptable Metals	AcceptableNon-Metals
Carbon steel (to 80°F)	Butadiene-acrylonitrile (NBR, Buna-N®) **(MEA only)**
Copper (to 80°F)	Carbon-graphite, resin impregnated
Hastelloy B®	Chlorinated polyether **(TEA only)**
Hastelloy C®	Epoxy compounds
Inconel®	Ethylene propylene diene (EPDM)
Monel®	Ethylene-terefluoroethylene (ETFE, Tefzel®)
Nickel	Fluorinated ethylene propylene (FEP)
Nickel resist	Fluoroelastomers (FKM, Viton A®, Fluorel®)
304 Stainless steel	Modified phenylene oxide (Noryl®)
316 Stainless steel	Natural rubber
20 Cb 3 Stainless steel	Polybutadiene (Isoprene)
Tantalum	Polyamides (Nylon® 12, Nylon® 66)
Titanium	Polychloroprene (Neoprene®)
	Polyester terephthalate (PET)
	Perfluoroalkoxy (PFA)
	Perfluoroelastomers (FPM, Kalrez®, Chemraz®, Kel-F®)
	Polypropylene **(except TEA)**
	Polysulfone **(except TEA)**
	Polyvinylidene fluoride (PVDF, Kynar®) **(TEA only)**
	Vinyl ester

Technical Data

Physical Properties	MEA	DEA	TEA
Chemical formula	$H_2NCH_2CH_2OH$	$HN(CH_2CH_2OH)_2$	$N(CH_2CH_2OH)_3$
Molecular weight, (g/mol)	61.08	105.14	149.19
Acidity/alkalinity, (pH)	11.5-12.2	10-12	10-12
Boiling point @ 760 mm Hg, (°C/°F)	170/338	268/514 (decomp.)	335/635 (decomp.)
Critical pressure, (Atmos.)	44.1	32.3	24.2
Critical temperature, (°C)	341.3	442.1	514.3
Coefficient of cubical expansion, (/°C)	0.00078	0.00065	0.00055
applicable range, (°C)	20-30	30-40	20-30
Density @ 20°C, (lbs/gal)	8.487	9.104 (@30°C/20°C)	9.354
@ 25°C, (g/ml)	1.008	1.093	1.120
Dielectric constant - liquid	37.7	22.81	29.36
Equivalent weight, (g/mol)	61-63	104-108	140-149
Explosive limits in air, vol. % - lower	5.5	-	-
- upper	17.0	-	-
Evaporation rate @ 25 °C			
n-butyl acetate - (=1.00)	<0.001	<0.005	0.015
n-butyl acetate - (155 seconds)		8.5 hrs.	2.9 hrs.

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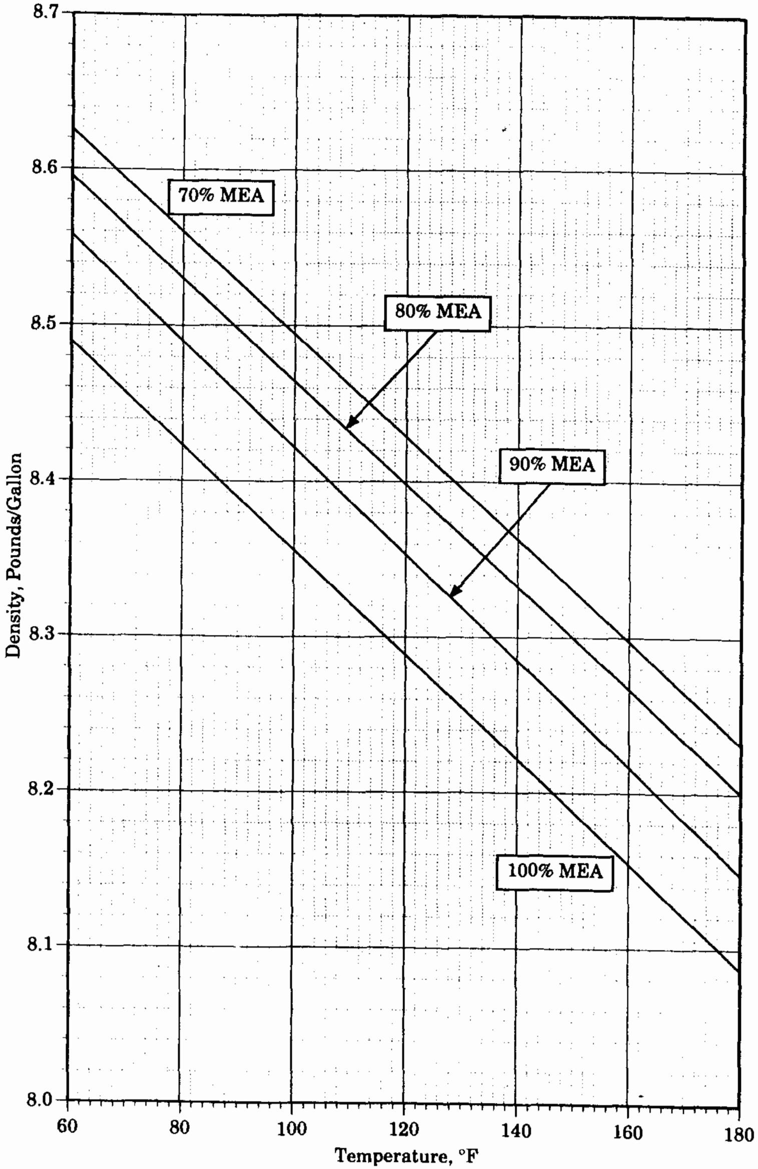
Table 14.60: (continued)

Physical Properties	MEA	DEA	TEA
Flammability rating	combustible	non-flammable	non-flammable
Flash point, (°C/°F) - Cleve. Open Cup	91/195	138/280	191/375
- Tag Closed Cup	85/186	146/295	194/382
- Pensky-Martin CC	-	166/330	210/410
Fire point, (°C/°F)	93/200	149/300	210/410
Freezing point, (°C/°F)	10.3/50.5	28/82	21/70
Heat of fusion, (BTU/lb^2)	144.35	102.75	78.41
Auto ignition temperature, (°C/°F)	410/770	662/1224	350/662
Kauri-butanol value	NA	NA	NA
Latent heat of vaporization @ B.P.			
- (cal/g)	199	-	-
- (BTU/lb)	360	287 (@166°C, 13.2 mm Hg)	176
Refractive index - liquid N 20°D	1.4540	1.4770	1.4835
Solubility @ 20°C, (% by wt) - In H_2O	100	95.4	100
- H_2O In	100	-	100
Solubility parameter, [Hildebrand units, (cal/cm^3)$^{1/2}$]	13.9	14.3	15.4
Specific gravity, (20°C/20°C)	1.018	1.092 (@30°C/20°C)	1.126
Specific heat, (cal/gm/°C, BTU/lb/°F) - liquid, (20°C)	0.644	0.593	0.555
Surface tension, (dynes/cm), Air @ 25°C	48.16	48.00	46.07
Thermal conductivity, liquid @ 35°C (BTU-ft/ft^2/hr/°F)	0.154	0.127	-
Vapor density, (g/L) air=1, (lbs/ft^3)	2.1	3.65	5.14
Vapor pressure @ 20°C, (mm. Hg)	0.67	<0.01	<0.01
Viscosity, liquid @ 25°C, (cps)	19	580	591
Antoine constants -A	8.02401	8.12303	8.2054
-B	1921.6	2315.46	2739.58
-C	203.2	173.3	175.7

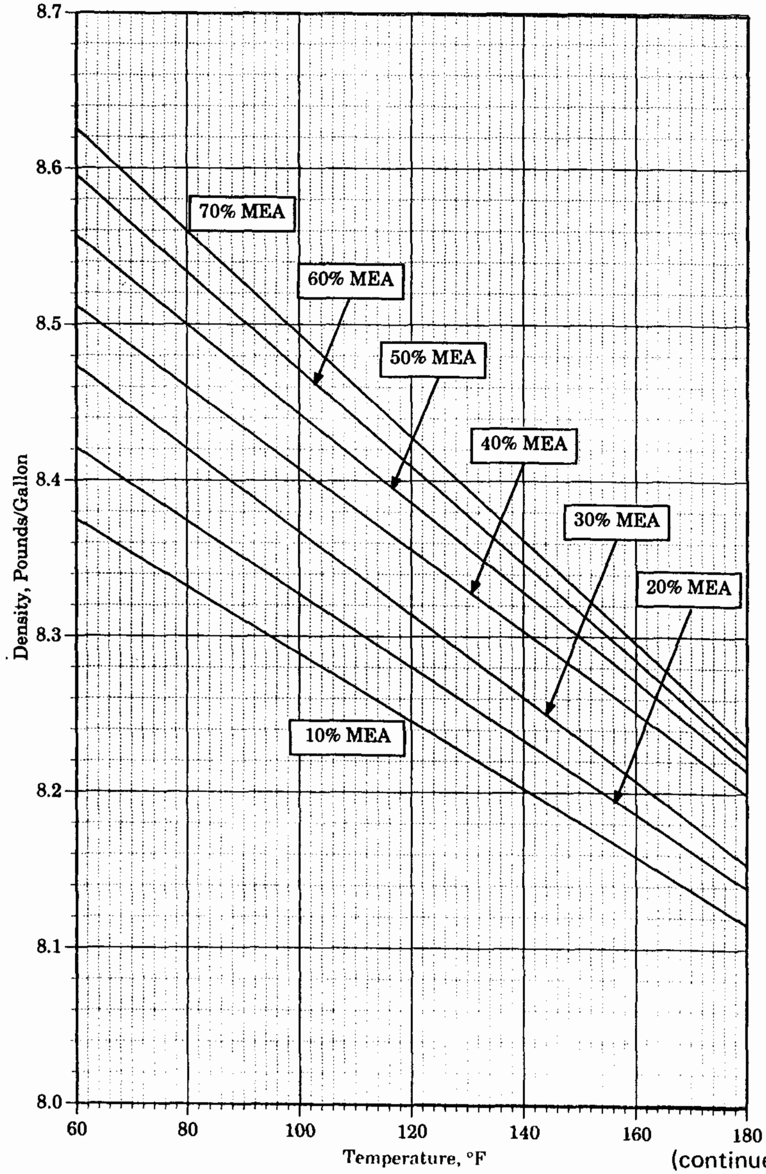
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Table 14.60: (continued)

Density vs. Temperature for Aqueous Solutions of Monoethanolamine



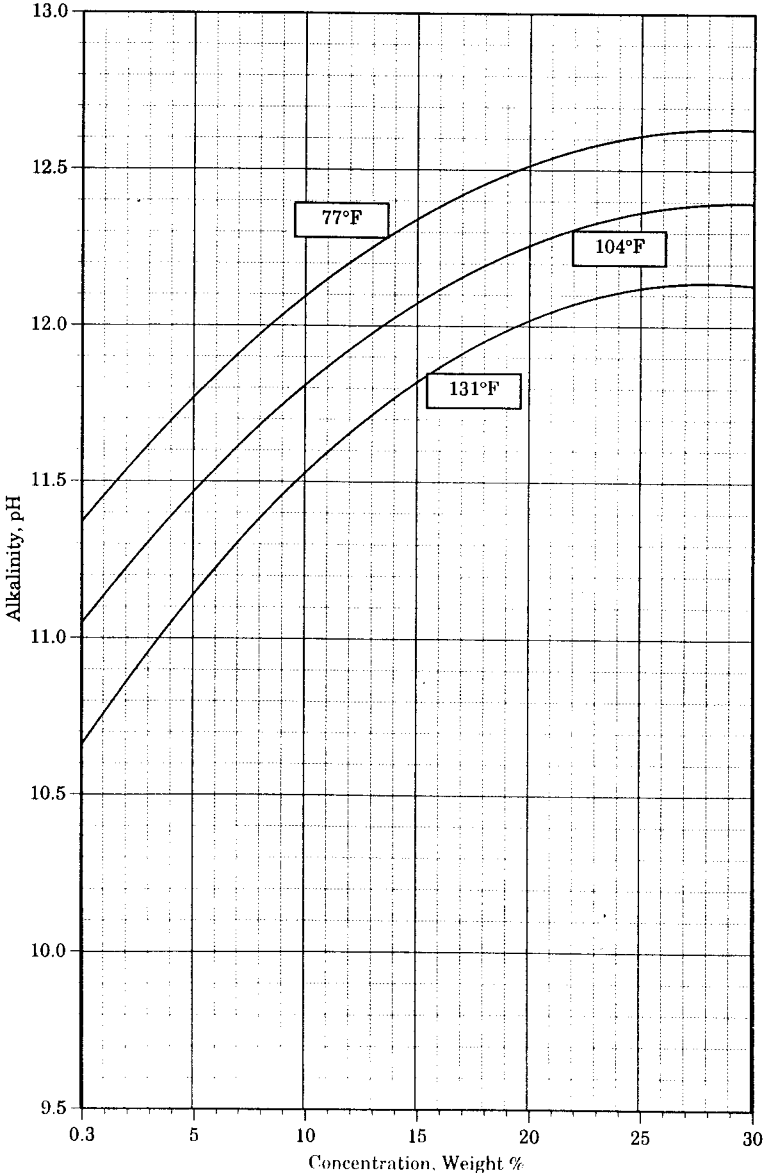
Density vs. Temperature for Aqueous Solutions of Monoethanolamine



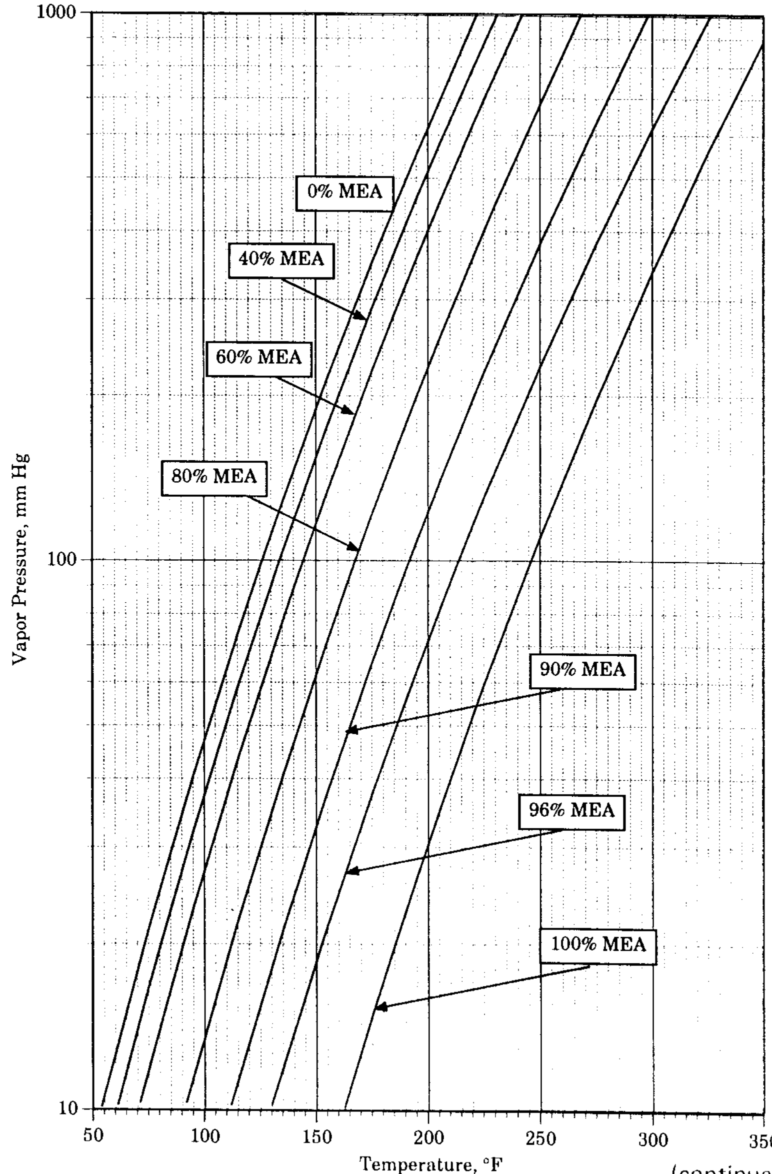
(continued)

Table 14.60: (continued)

pH vs. Concentration for Aqueous Solutions of Monoethanolamine



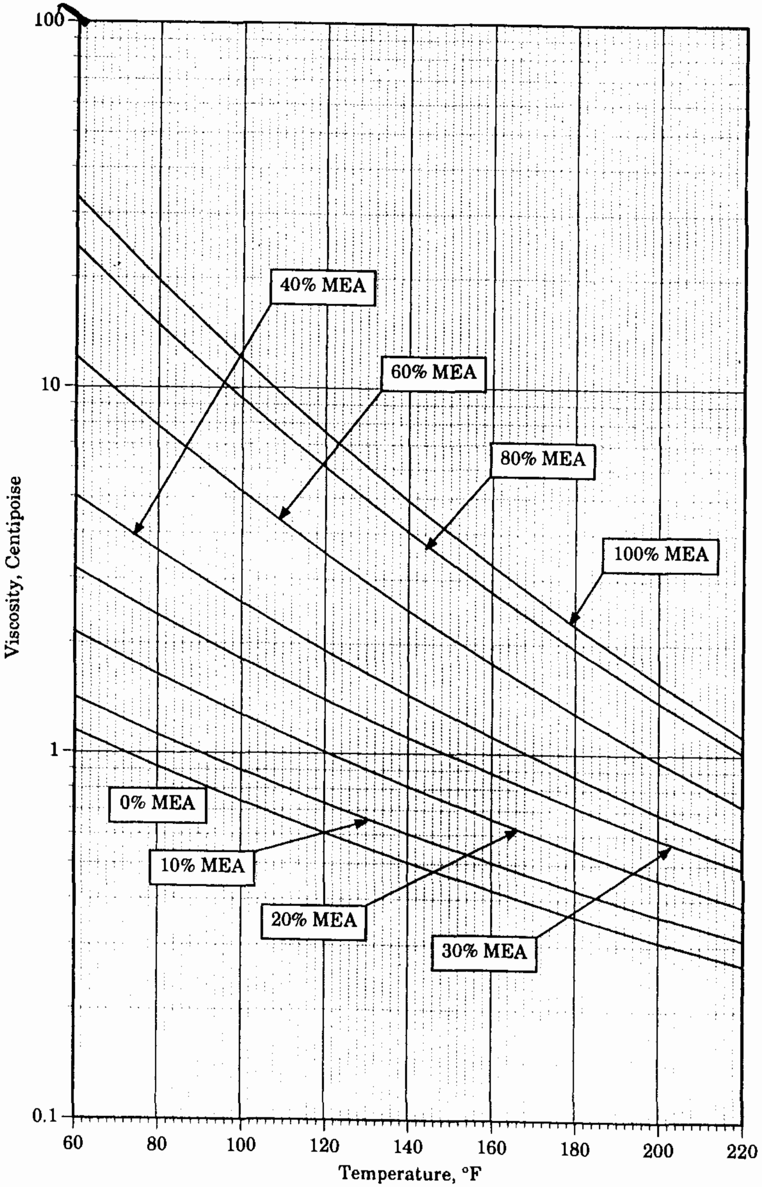
Vapor Pressure vs. Temperature for Aqueous Solutions of Monoethanolamine



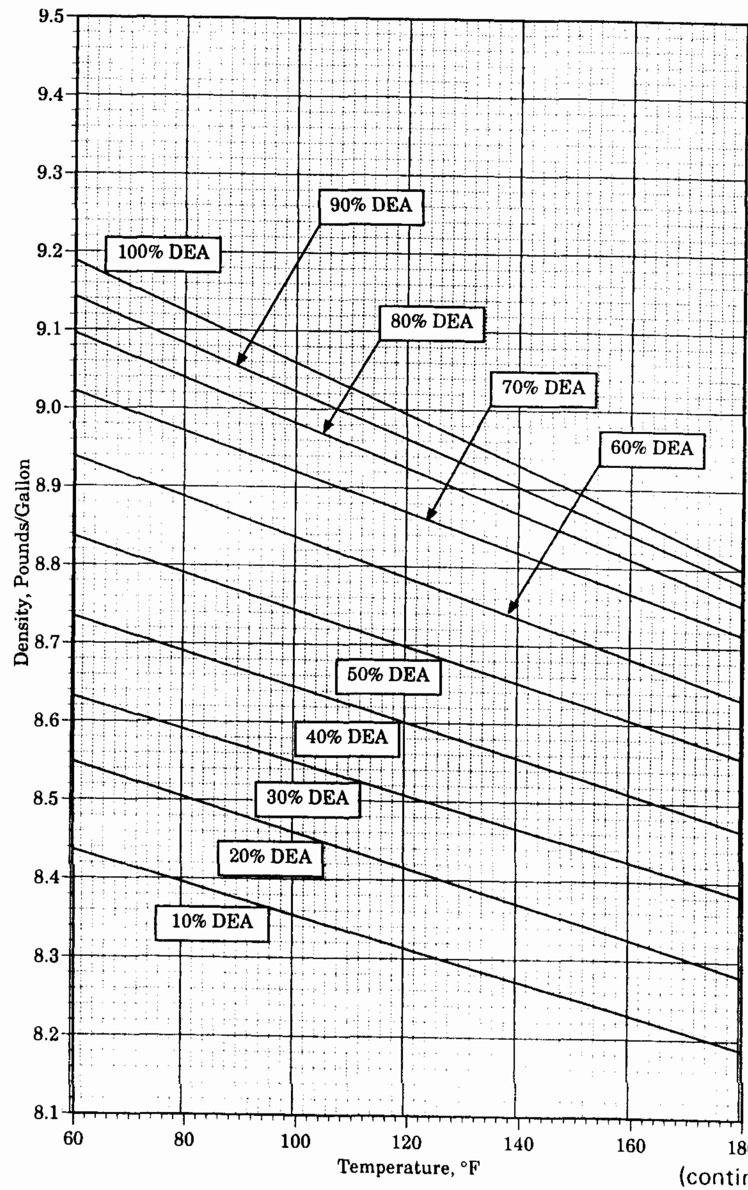
(continued)

Table 14.60: (continued)

Viscosity vs. Temperature for Aqueous Solutions of Monoethanolamine



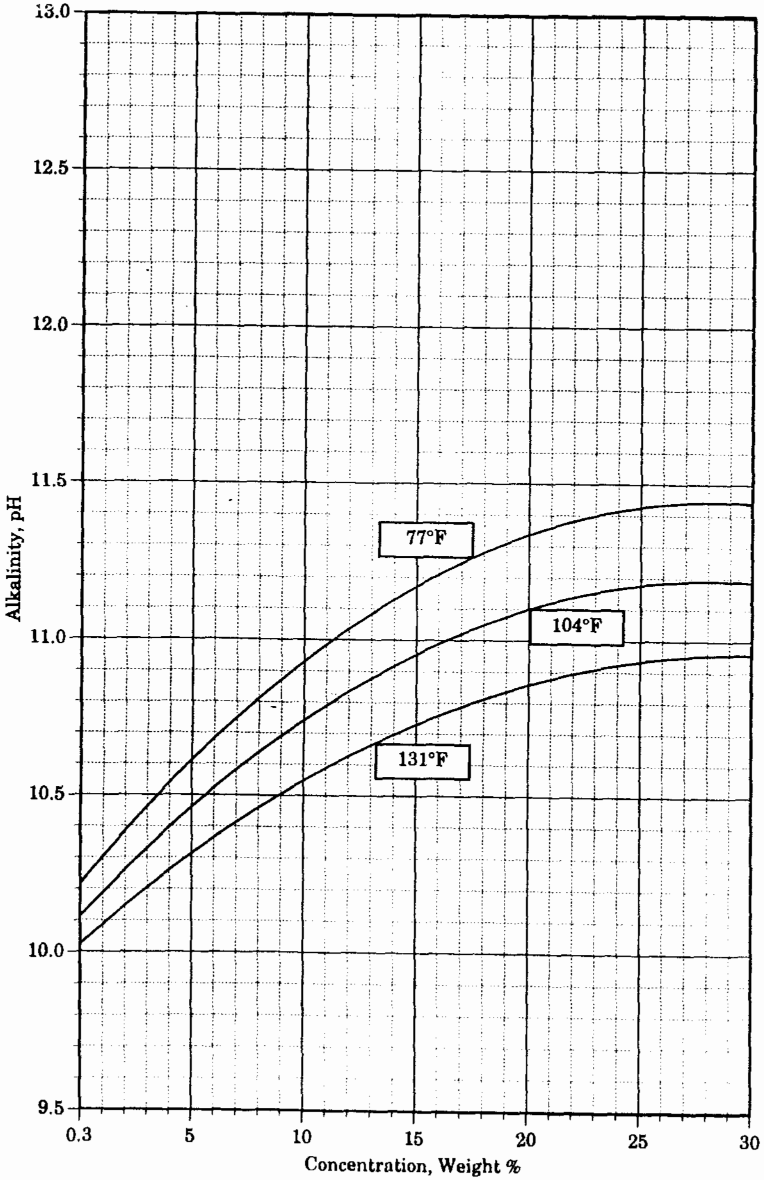
Density vs. Temperature for Aqueous Solutions of Diethanolamine



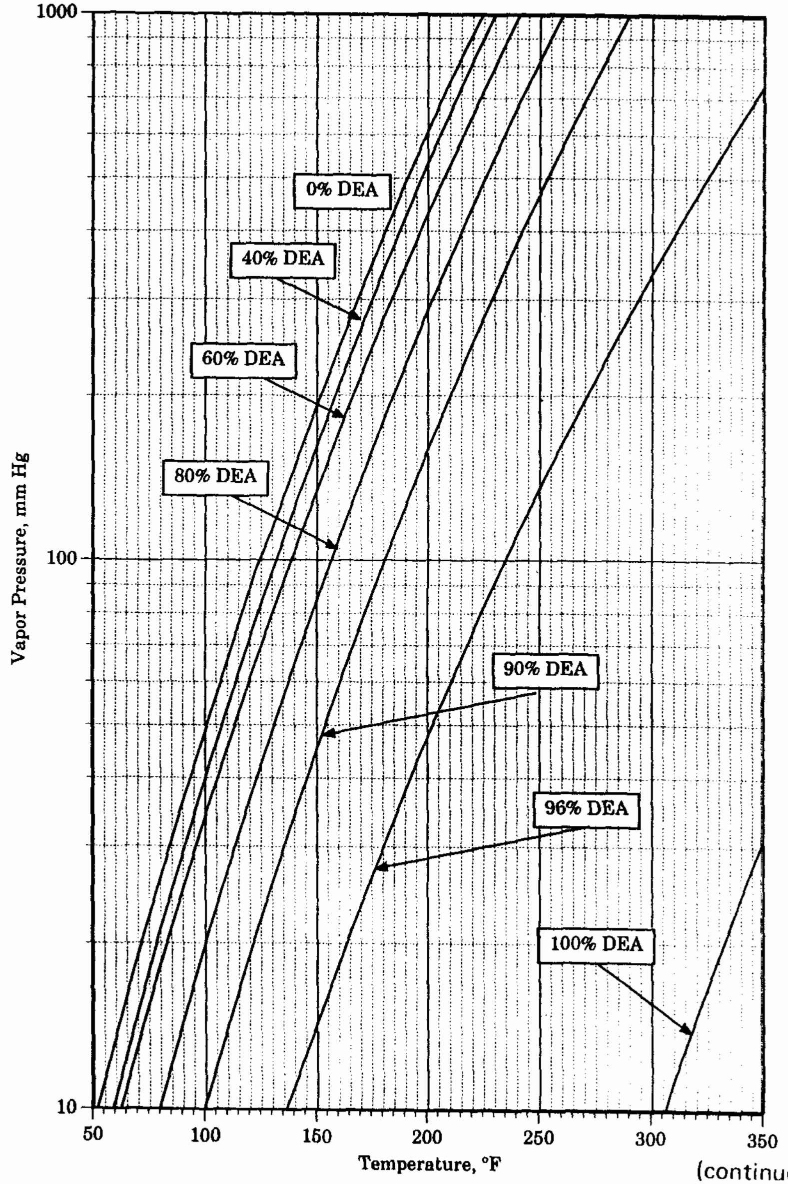
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Table 14.60: (continued)

pH vs. Concentration for Aqueous Solutions of Diethanolamine



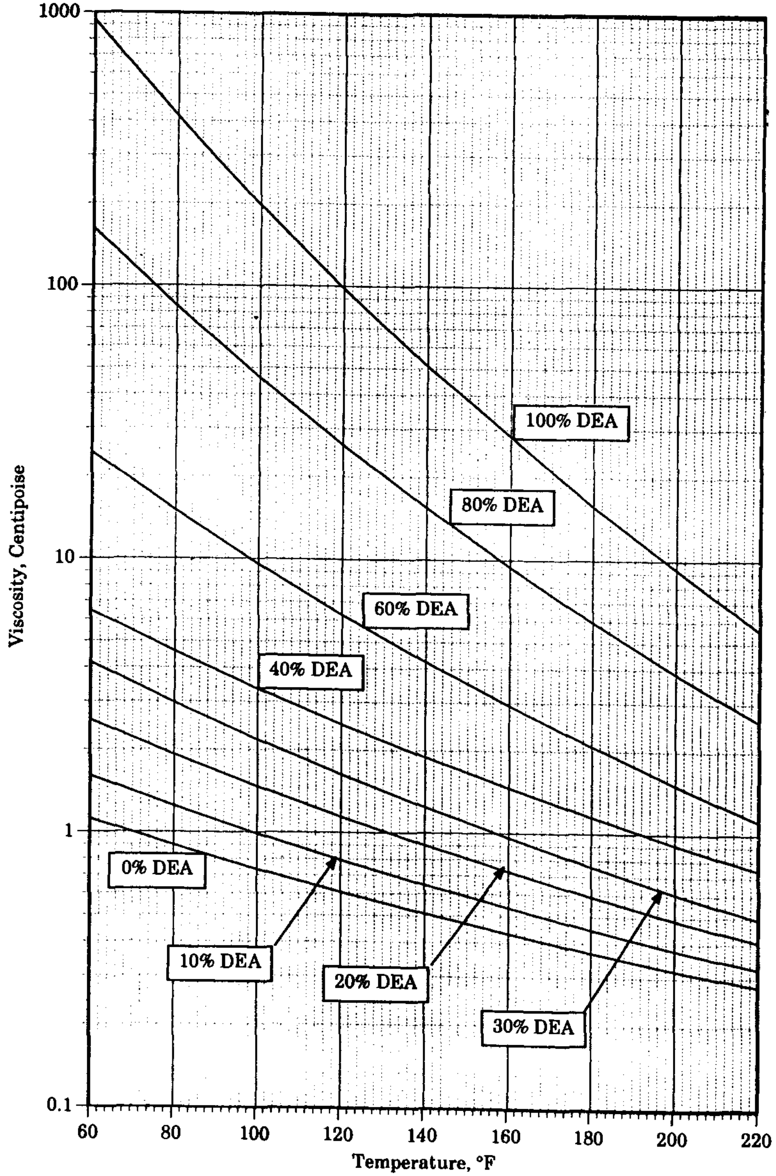
Vapor Pressure vs. Temperature for Aqueous Solutions of Diethanolamine



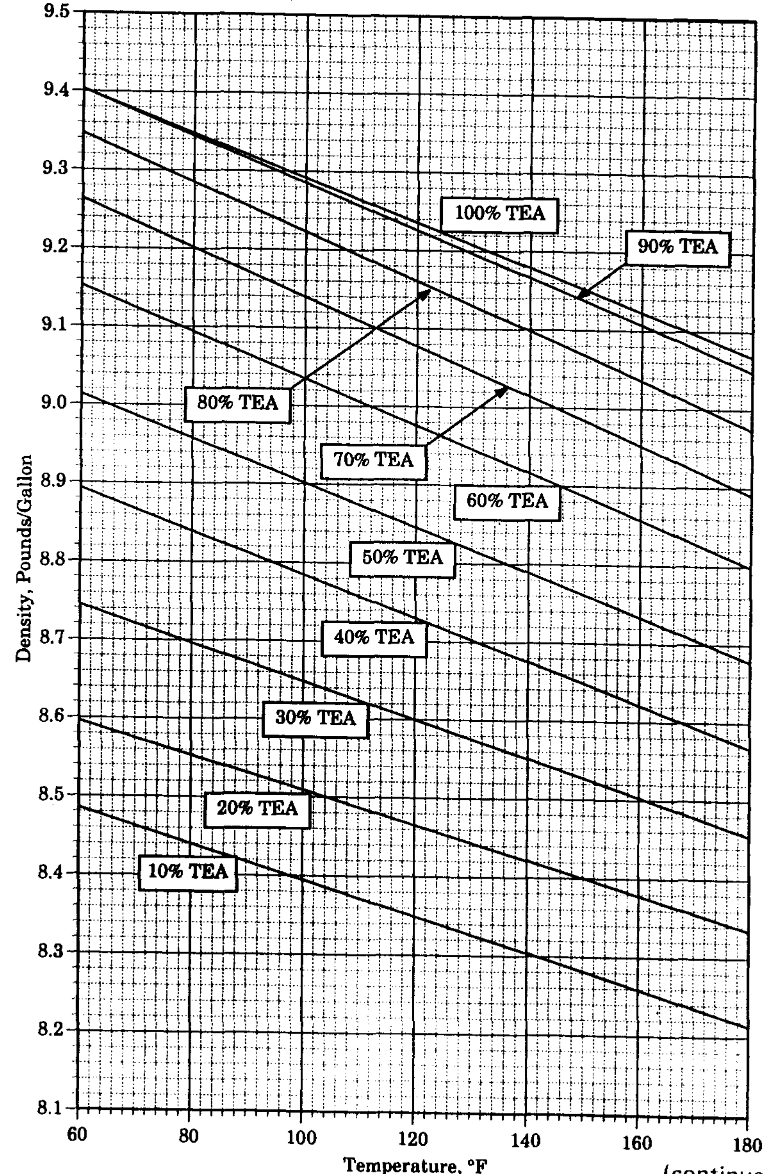
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Table 14.60: (continued)

Viscosity vs. Temperature for Aqueous Solutions of Diethanolamine

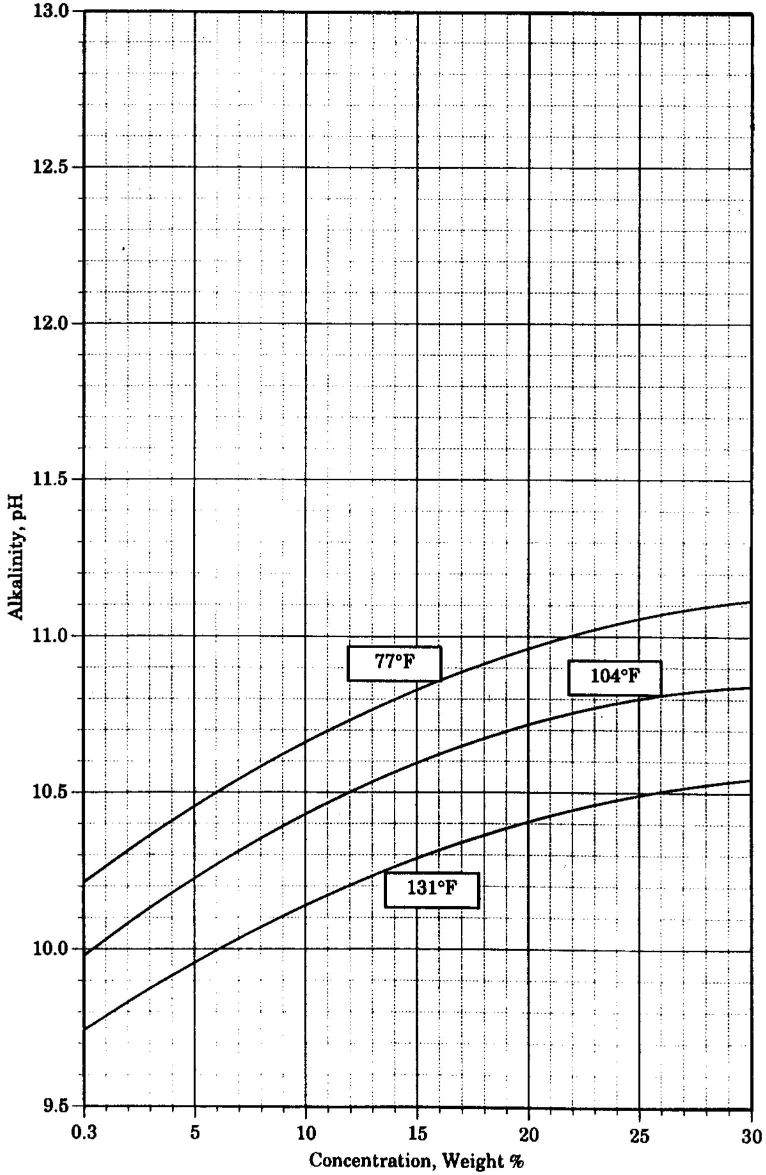


Density vs. Temperature for Aqueous Solutions of Triethanolamine

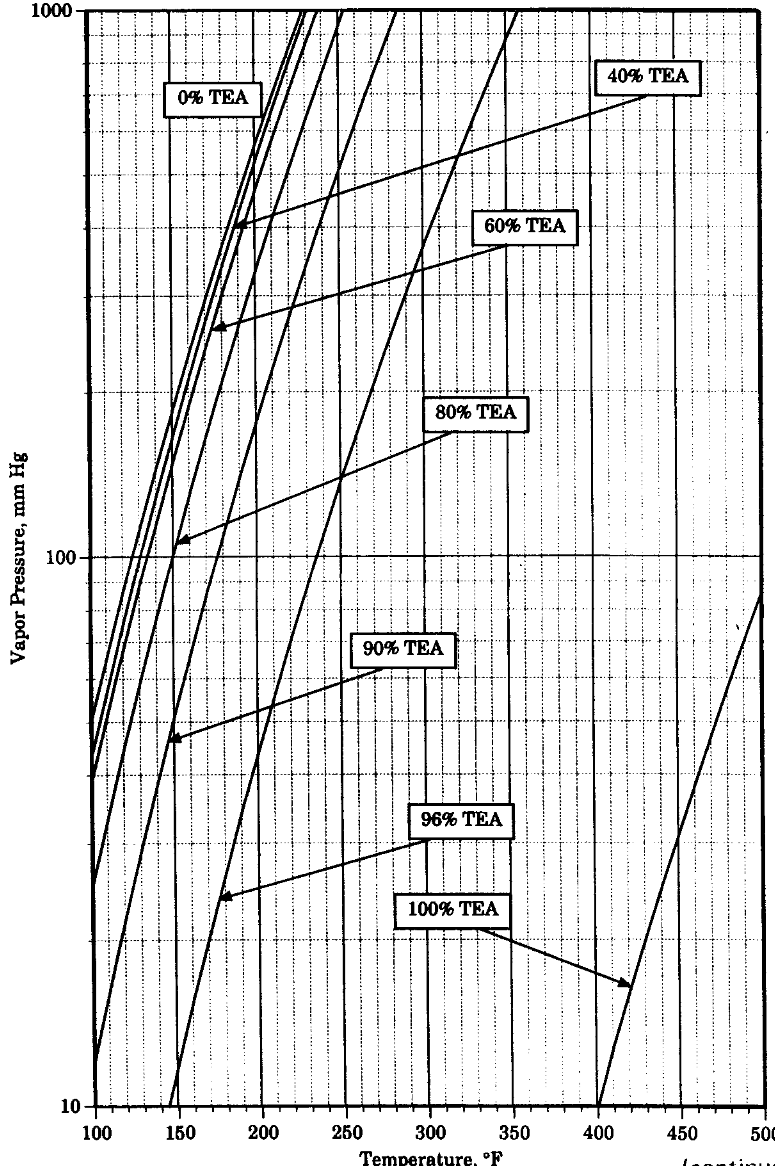


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pH vs. Concentration for Aqueous Solutions of Triethanolamine



Vapor Pressure vs. Temperature for Aqueous Solutions of Triethanolamine

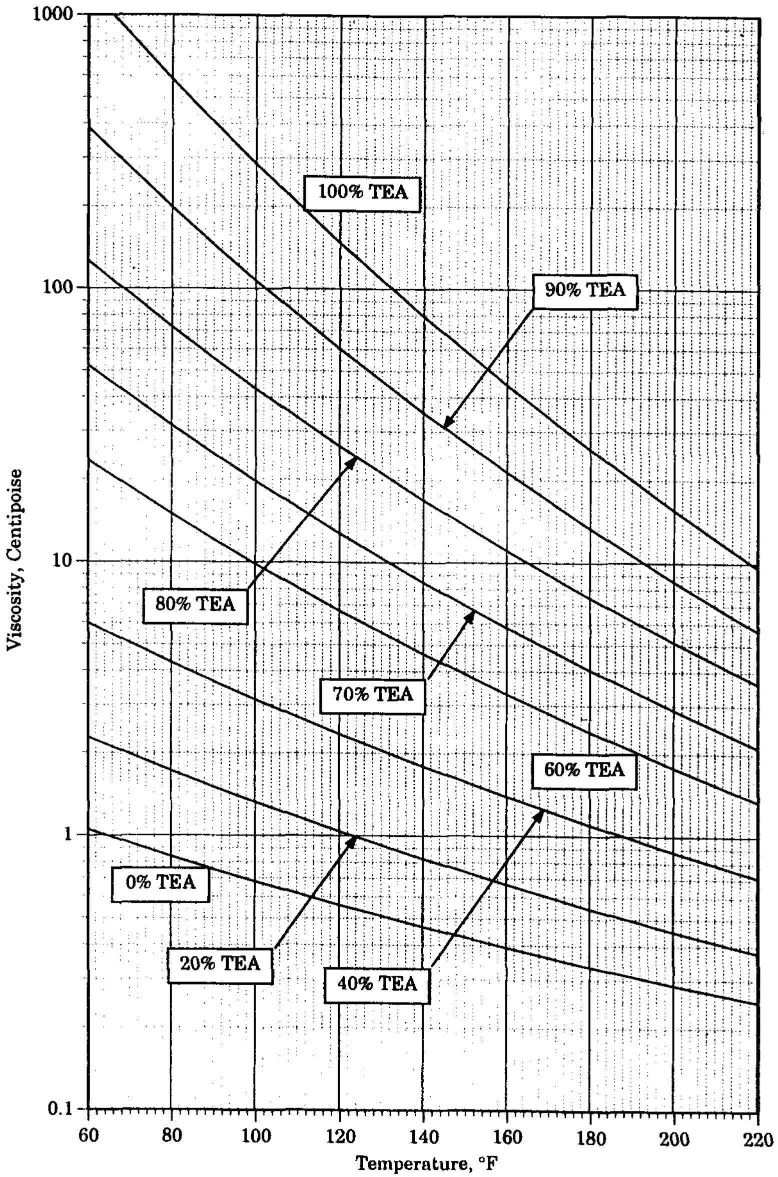


(1927 – 2000)

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Table 14.60: (continued)

Viscosity vs. Temperature for Aqueous Solutions of Triethanolamine



Freezing Point vs. Concentration for Aqueous Ethanolamine Solutions

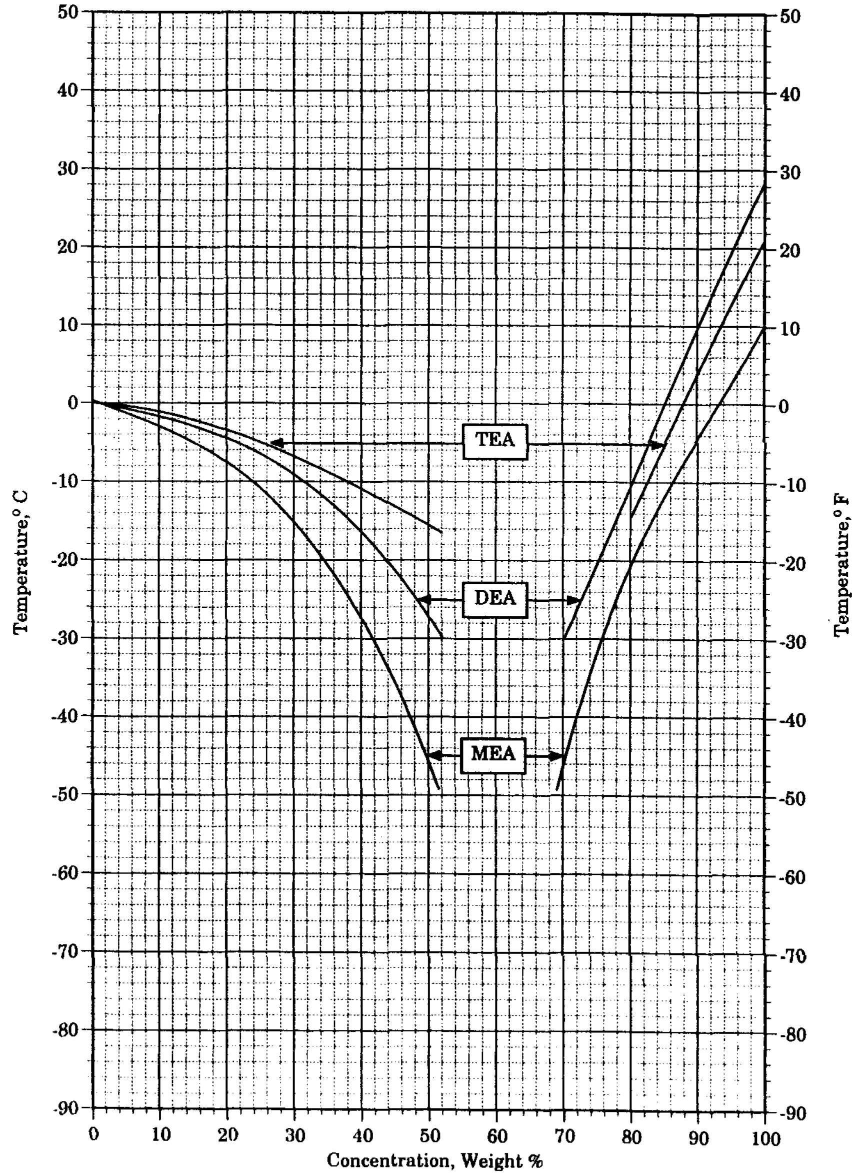


Table 14.61: Union Carbide Ethyleneamines *(19)*

Typical Physical Properties

Ethyleneamine	Molecular Weight	Apparent Specific Gravity at 20/20°C	Freezing Point, °C	Vapor Pressure at 20°C, mm Hg
Ethylenediamine	60.10	0.898	11	10.40
Diethylenetriamine	103.17	0.952	-39	0.08
Triethylenetetramine	146.24(1)	0.980	-35	<0.01
Tetraethylenepentamine UHP	189.30(1)	0.994	-46(6)	<0.01
Heavy Polyamine X	275(2)	1.015	-32(6)	<0.01
Piperazine, 65%	86.14(3)	1.036(4)	41	6.28
Piperazine, Anhydrous	86.14	0.877(5)	110	0.10(7)
Aminoethylpiperazine	129.21	0.986	-17	<0.01
Aminoethylethanolamine	104.15	1.030	-45(6)	<0.01

Ethyleneamine	Boiling Point, °C 760 mm Hg	50 mm Hg	10 mm Hg	Δ Boiling Point/Δp, 750-770 mm, °C per mm Hg	Absolute Viscosity at 20°C, cP
Ethylenediamine	117.0	47.8	19.4	0.043	1.80
Diethylenetriamine	206.9	123.3	88.9	0.052	7.16
Triethylenetetramine	277(8)	183	144	0.058	26.0
Tetraethylenepentamine UHP	288(8)	215	184	0.045	83.1
Heavy Polyamine X	–	279(8)	236	–	460.7
Piperazine, 65%	116	54	27	0.036	22.5(10)
Piperazine, Anhydrous	146.1	–(9)	–(9)	0.037	0.73(11)
Aminoethylpiperazine	221.0	134.3	100.9	0.056	15.4
Aminoethylethanolamine	242.8	161.3	127.0	0.049	140.6

	Electrical Conductivity at 25°C, micromhos/cm	Ionization Constant, K1, at 25°C in Water	Dielectric Constant at 23°C	Solubility in Water at 20°C, % by wt
Ethylenediamine	7.52	0.73×10^{-4}	13.29	100
Diethylenetriamine	0.86	0.65×10^{-4}	12.22	100
Triethylenetetramine	0.24	0.63×10^{-4} (2)	10.24	100(12)
Tetraethylenepentamine UHP	0.091	0.72×10^{-4} (2)	9.32	100(12)
Heavy Polyamine X	0.092	0.95×10^{-4} (2)	8.72	100(12)
Piperazine, 65%	49.4(10)	0.43×10^{-4} (3)	–(9)	100(10)
Piperazine, Anhydrous	–(9)	0.43×10^{-4}	–(9)	14
Aminoethylpiperazine	0.007	0.40×10^{-4}	7.13	100
Aminoethylethanolamine	0.63	0.31×10^{-4}	19.13	100

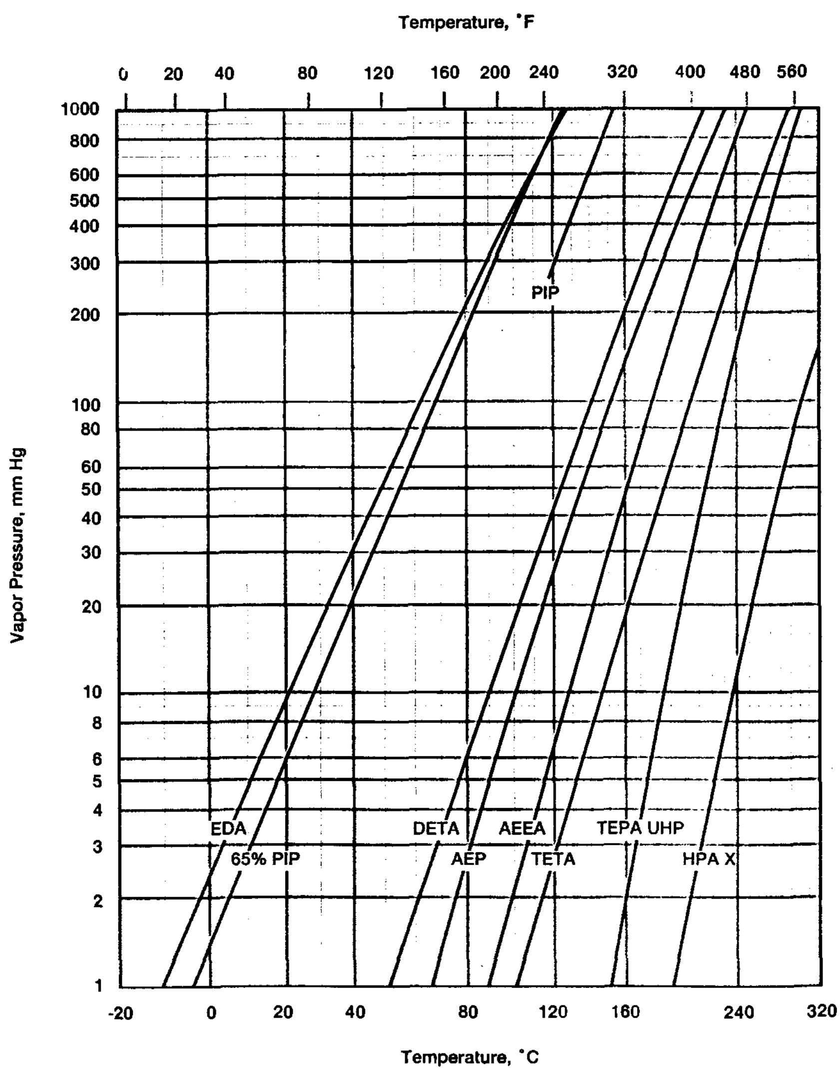
(continued)

Table 14.61: (continued)

	Refractive Index, $n_D 20°C$	Specific Heat at 20°C, cal/g • °C	Heat of Vaporization at 760 mm Hg, BTU/lb[15]	Heat of Combustion at 25°C, BTU/lb	Heat of Formation at 25°C, BTU/lb[16]
Ethylenediamine	1.457	0.68	270	-13251	-569
Diethylenetriamine	1.483	0.65	197	-13910	-403
Triethylenetetramine	1.499	0.63	162	-14353	-162[1]
Tetraethylenepentamine UHP	1.505	0.61	162	-14487	-139[1]
Heavy Polyamine X	1.513	0.58	99	-14643	—
Piperazine, 65%	—[9]	0.78[13]	528	-9261	—
Piperazine, Anhydrous	—[9]	0.63[14]	250	-14696	-304
Aminoethylpiperazine	1.501	0.52	152	-14744	-256
Aminoethylethanolamine	1.486	0.64	237	-12395	-1193

(1) Linear component only
(2) Typical molecular weight
(3) For Piperazine, Anhydrous
(4) At 42°C/42°C
(5) At 130°C/20°C
(6) Pour point
(7) Vapor pressure of the solid
(8) Extrapolated; with decomposition
(9) Solid at this condition
(10) At 42°C
(11) At 130°C
(12) Forms hydrate with time
(13) At 42°C; melting point 36°C, heat of fusion 50.74 cal/g
(14) At 130°C; melting point 109.6°C, heat of fusion 72.83 cal/g
(15) Estimated from vapor pressure using Clausius-Clapeyron equation
(16) Calculated from gross heat of combustion

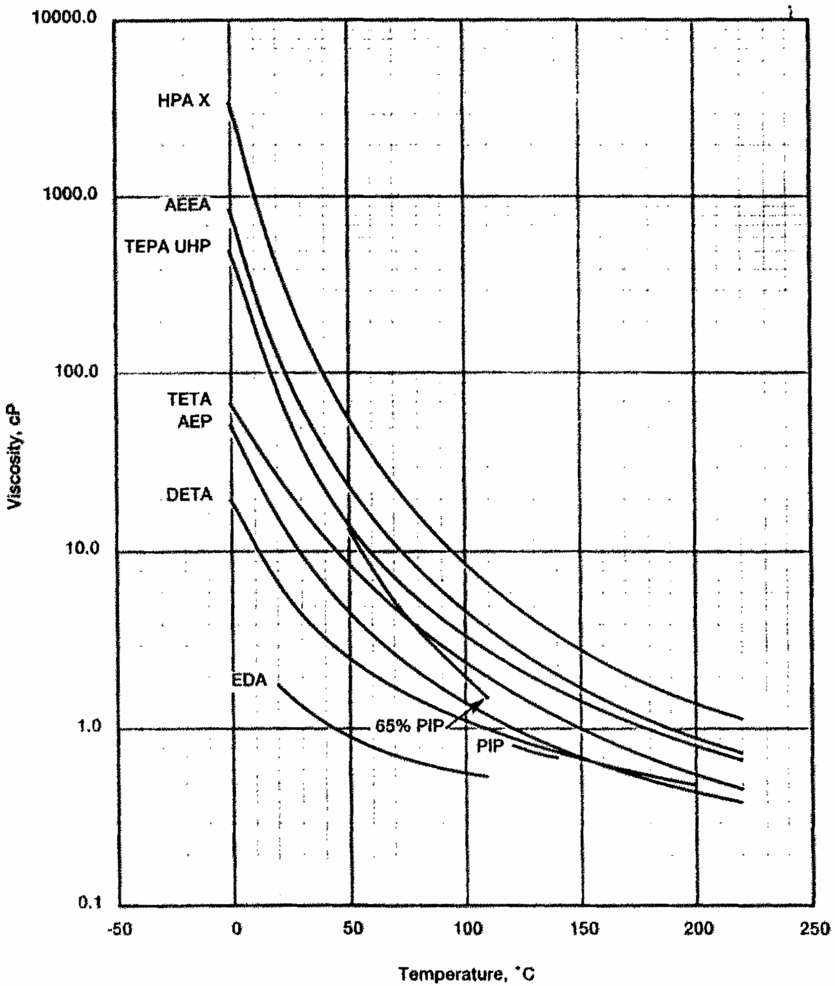
Ethyleneamines, Vapor Pressure vs. Temperature



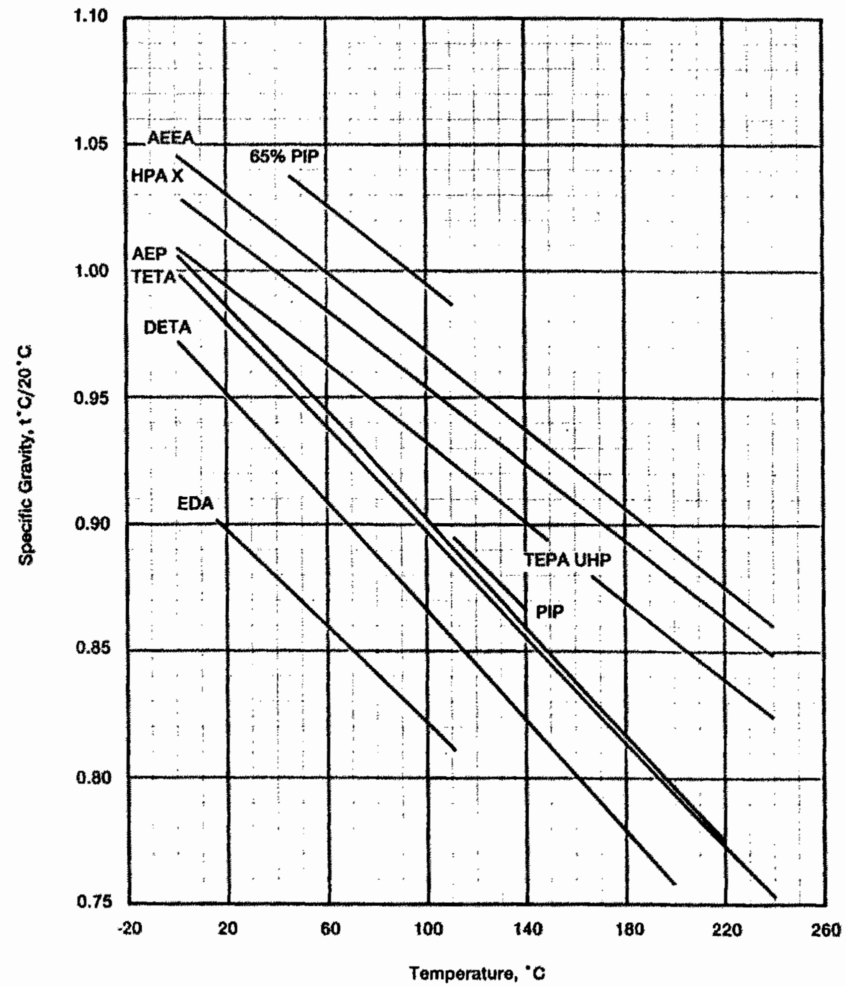
(continued)

Table 14.61: (continued)

Ethyleneamines, Viscosity vs. Temperature



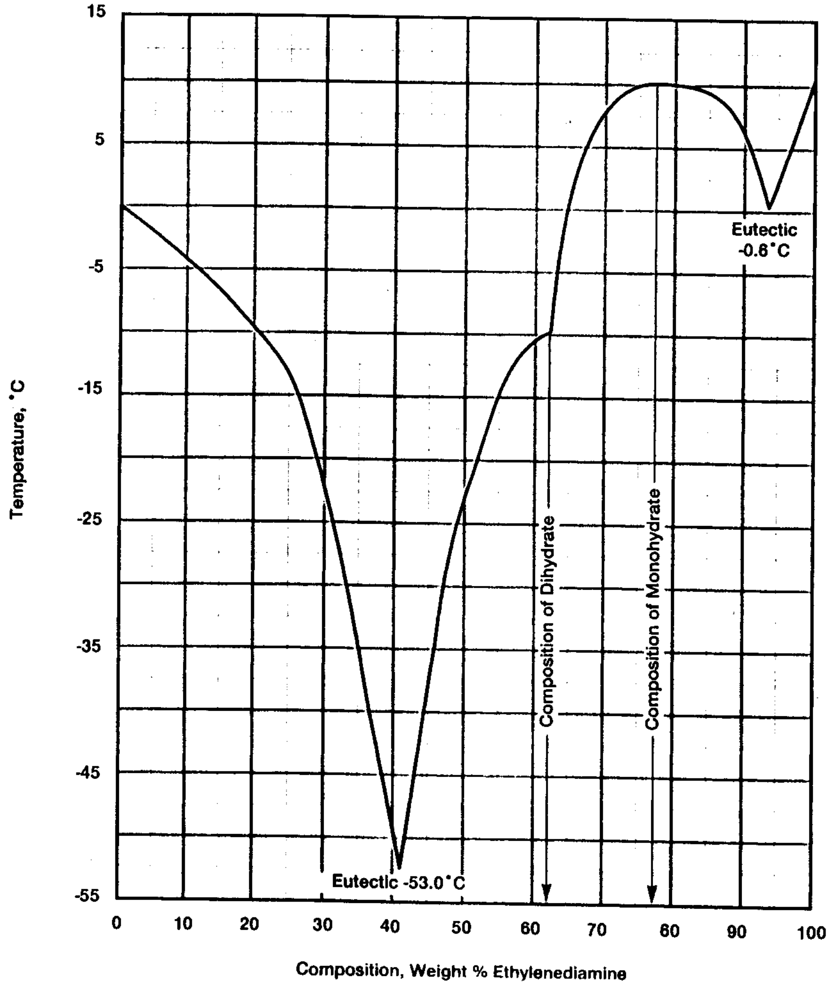
Ethyleneamines, Specific Gravity vs. Temperature



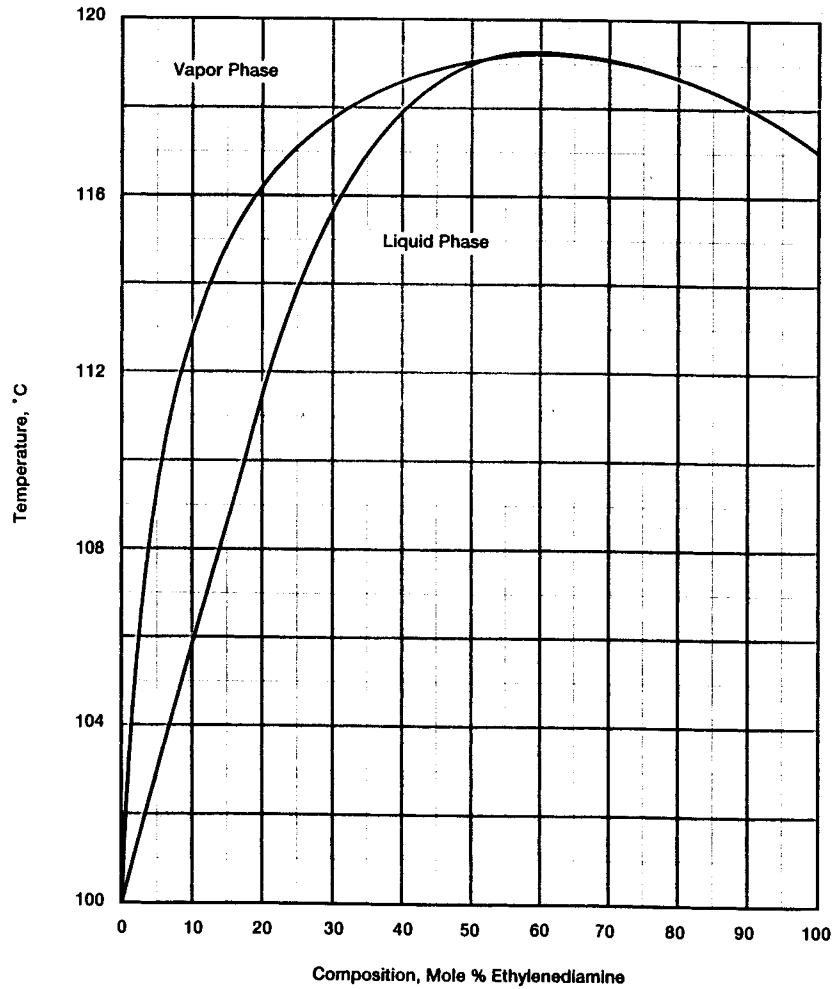
(continued)

Table 14.61: (continued)

Ethylenediamines Aqueous Solutions, Freezing Point vs. Composition

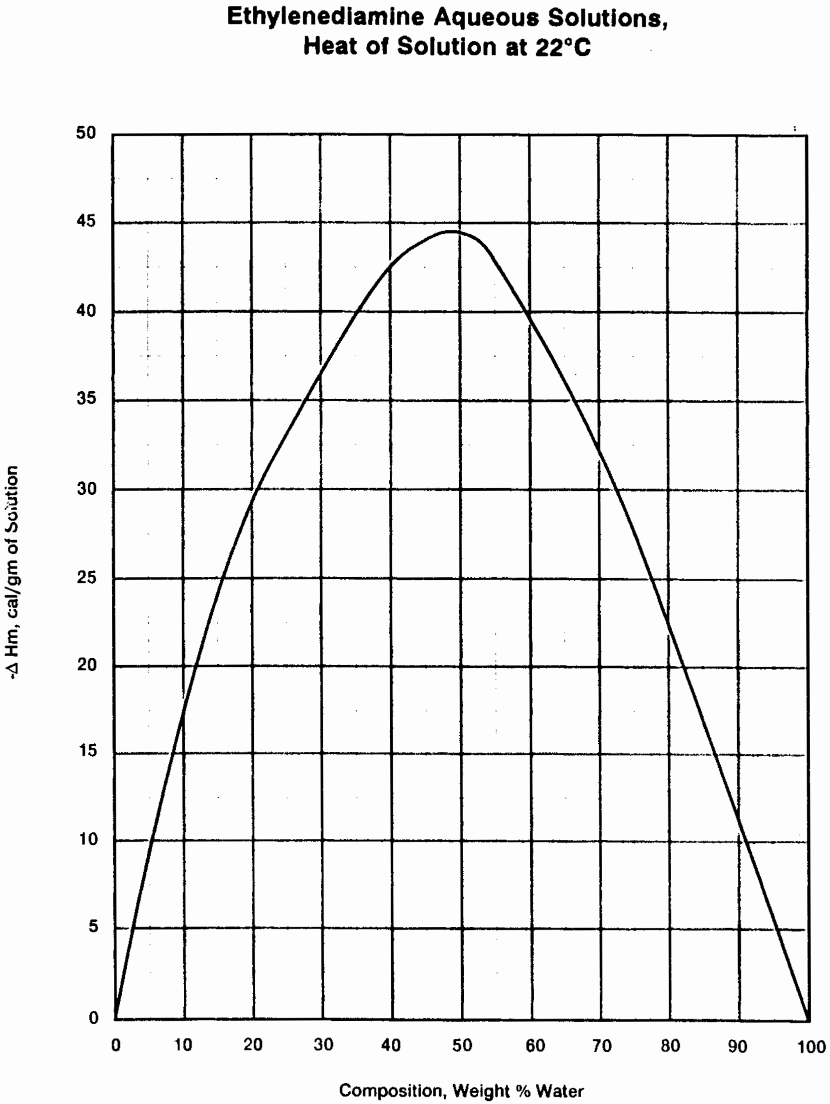


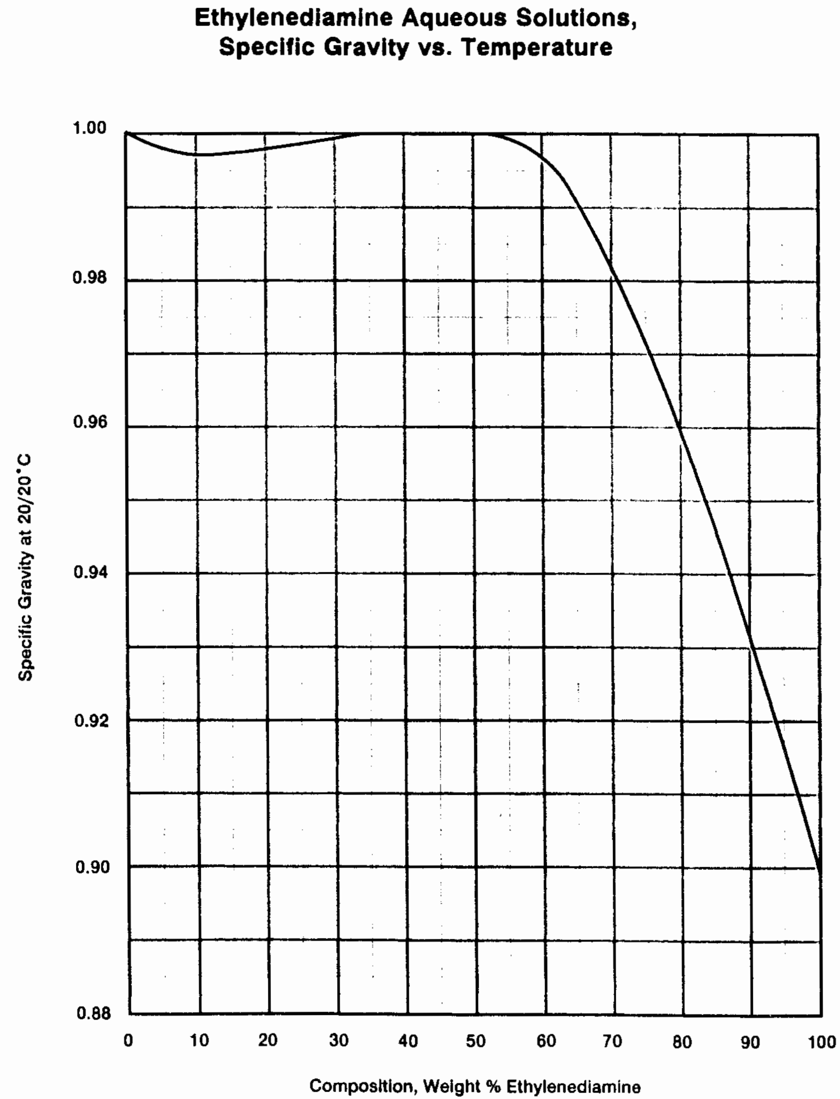
Ethylenediamine Aqueous Solutions, Vapor–Liquid Equilibria at 760 mm HG



(continued)

Table 14.61: (continued)

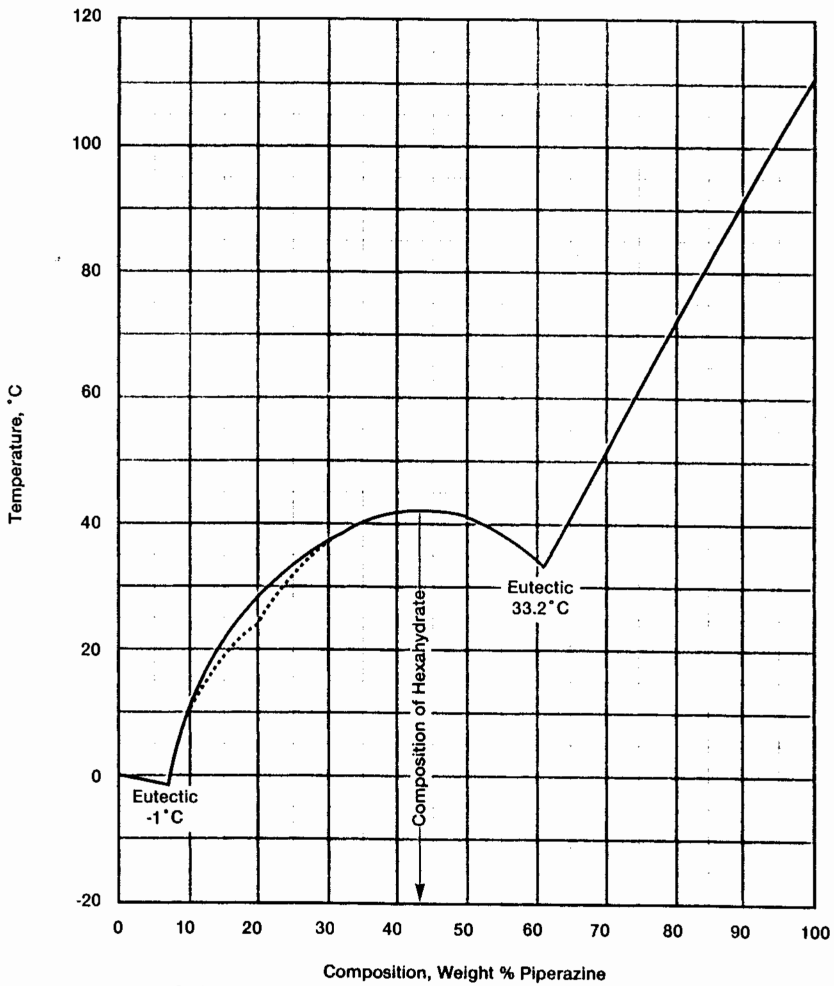




(continued)

Table 14.61: (continued)

Piperazine Aqueous Solutions, Freezing Point vs. Composition



Studies show evidence of a metastable freezing point in the region of 20 wt.% piperazine

Piperazine Aqueous Solutions, Vapor–Liquid Equilibria at 760 mm Hg

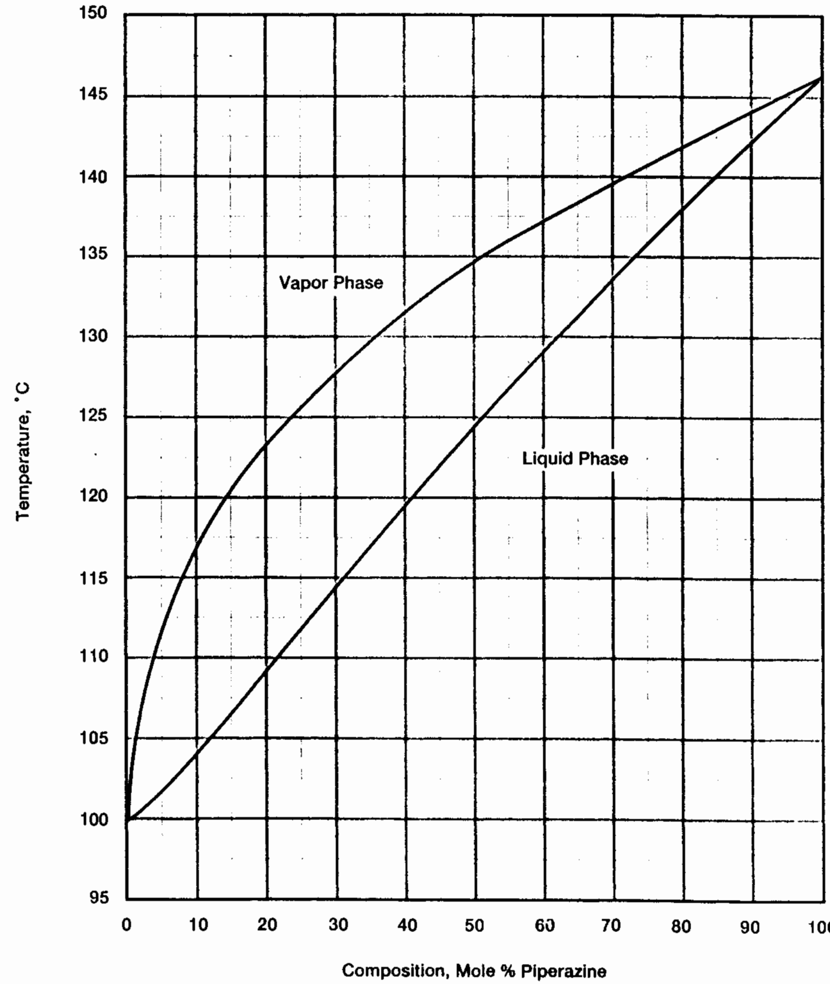


Table 14.62: Union Carbide Ethanolamines ***(19)***

Typical Properties of Union Carbide Ethanolamines
(Determined on Purified Samples)

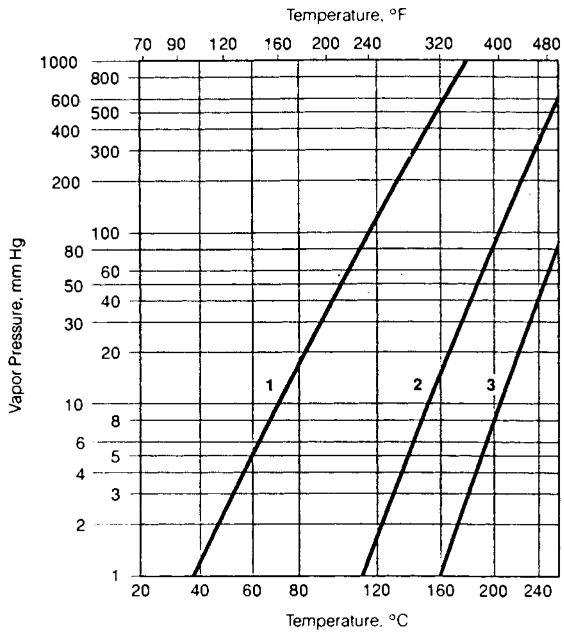
	Monoethanolamine	**Diethanolamine**	**Triethanolamine**
Formula	$H_2NCH_2CH_2OH$	$HN(CH_2CH_2OH)_2$	$N(CH_2CH_2OH)_3$
Molecular Weight	61.08	105.14	149.19
Apparent Sp. Gr. at 20/20°C	1.0179	1.09199[a]	1.1258[f]
ΔSp. Gr./Δt at (20/30°C)	0.00078	0.00065[b]	0.00055
Boiling Point at 760mm Hg, °C	170.8	268[c]	335.4[c]
at 50mm Hg, °C	101	187	245
at 10mm Hg, °C	71	151	205
Vapor Pressure at 20°C, mm Hg	<1	<0.01	<0.01
Absolute Viscosity at 20°C, cP	24.1	—	921[f]
at 30°C, cP	16.2	380	404
Freezing Point, °C(°F)	10.5 (50.9)	28.0 (82.4)[e]	21.6 (70.9)[e]
Solubility at 20°C, % by wt			
In Water	Complete	96.4	Complete[f]
Water In	Complete	—	Complete[f]
Solubility in Organic Liquids at 25°C, % by wt			
Acetone	Complete	Complete[f]	Complete
Benzene	0.6	0.03	2
Carbon Tetrachloride	0.1	0.01	Complete
Ethyl Ether	0.7	0.5	2
Heptane	0.1	0.03	<0.03
Methanol	Complete	Complete[f]	Complete
Surface Tension, Dynes/cm	48.3[d]	48.5[g]	48.9[d]
Refractive Index, n_D^{20}	1.4539	1.4747[g]	1.4852[f]
$\Delta N_D/\Delta t$ at 20 to 40°C per °C	0.00034	0.00027[b]	0.00020
Flash Point, °F	185[h]	336[i]	407[i]

(a) At 30/20°C
(b) at 30 to 40°C
(c) Extrapolated (decomposes)
(d) At 25°C
(e) Supercools easily
(f) Supercooled liquid
(g) At 30°C
(h) Determined by ASTM Method D 56, using the Tag Closed Cup
(i) Determined by ASTM Method D 93, using the Pensky-Martens Closed Cup

(continued)

Table 14.62: (continued)

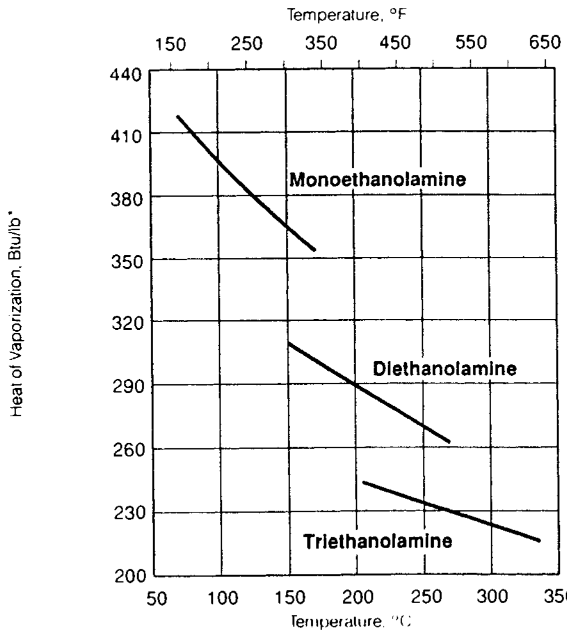
Vapor Pressure of Ethanolamines vs Temperature



NOTE:
Ethanolamines begin decomposing at temperatures above 200°C and can undergo self-sustained decomposition at temperatures above 260°C.

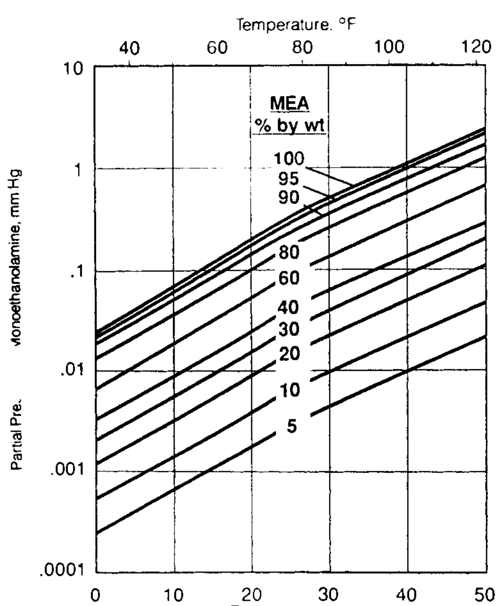
1 Monoethanolamine
2 Diethanolamine
3 Triethanolamine

Heat of Vaporization of Ethanolamines

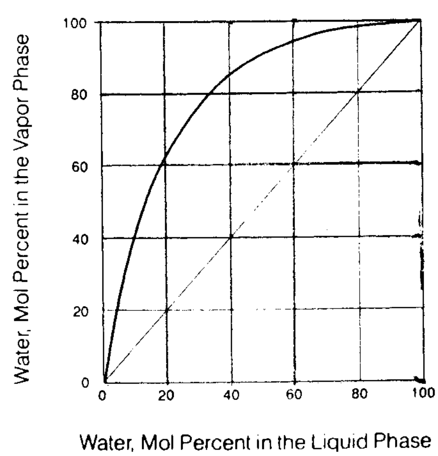


* 1 Btu/lb = 0.55555556 cal/g

Partial Pressures of Monoethanolamine in Aqueous Solutions at Various Contact Temperatures



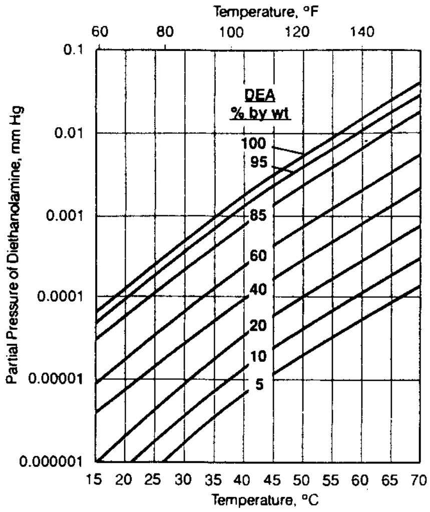
Liquid-Vapor Equilibria of Aqueous Monoethanolamine Solutions at 760 mm Hg



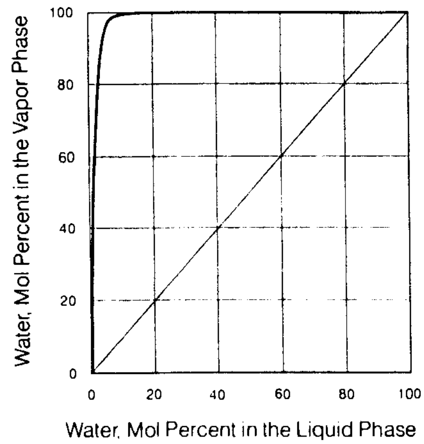
(continued)

Table 14.62: (continued)

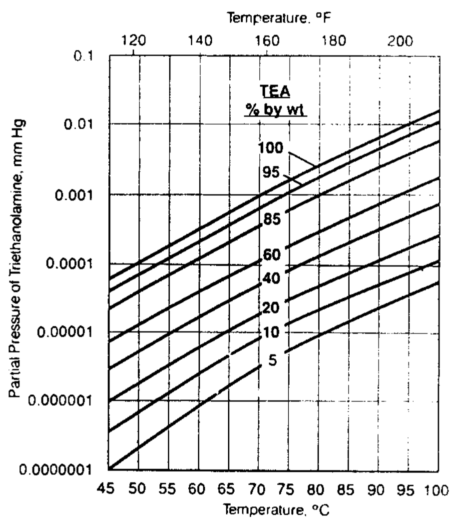
Partial Pressures of Diethanolamine in Aqueous Solutions at Various Contact Temperatures



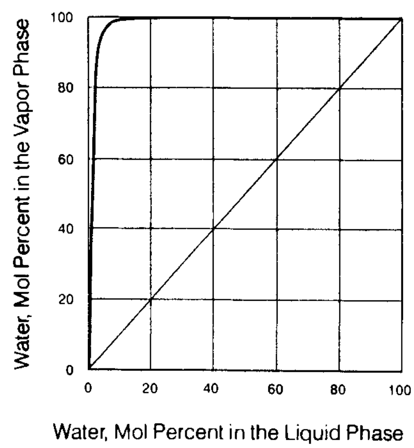
Liquid–Vapor Equilibria of Aqueous Diethanolamine Solutions at 760 mm Hg



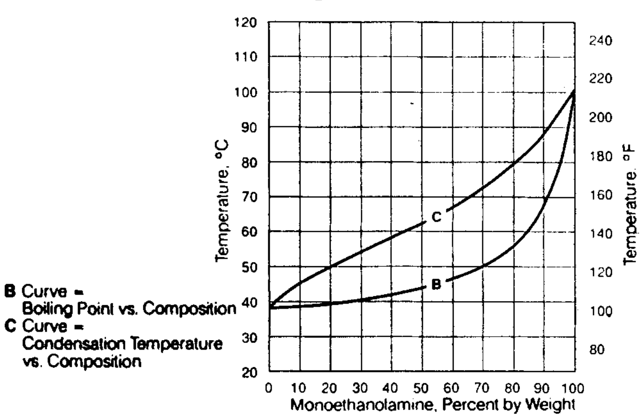
Partial Pressures of Triethanolamine in Aqueous Solutions at Various Contact Temperatures



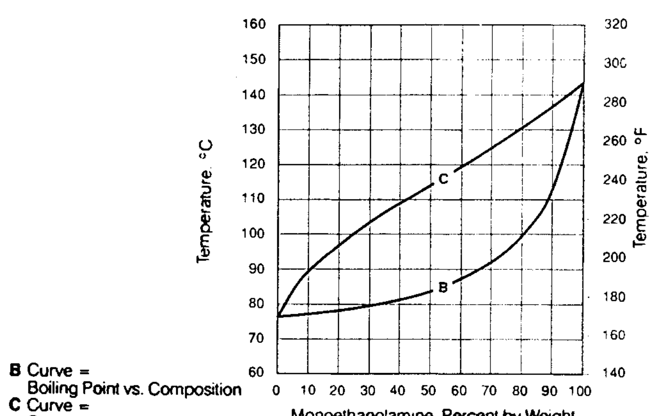
Liquid–Vapor Equilibria of Aqueous Triethanolamine Solutions at 760 mm Hg



Boiling Points and Condensation Temperatures of Aqueous Monoethanolamine Solutions at 50 mm Hg Absolute



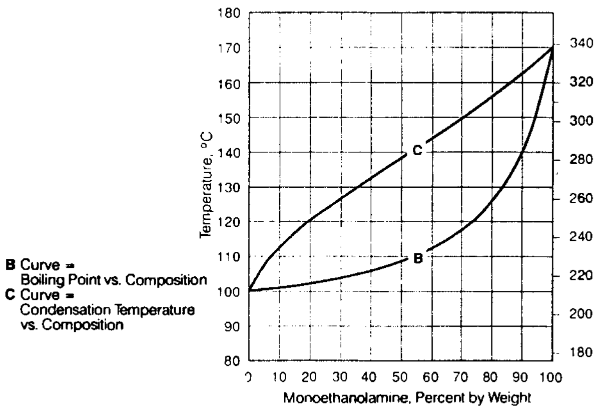
Boiling Points and Condensation Temperatures of Aqueous Monoethanolamine Solutions at 300 mm Hg Absolute



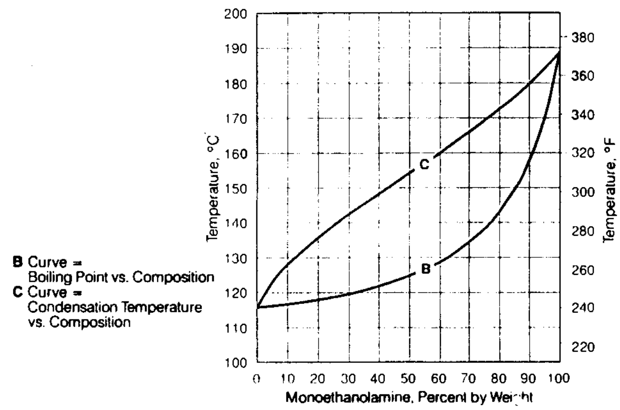
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Table 14.62: (continued)

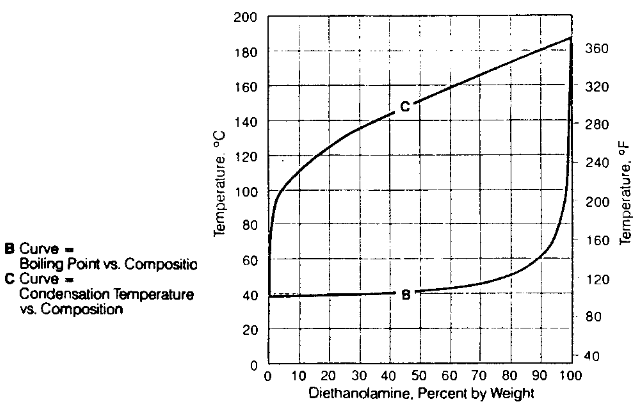
Boiling Points and Condensation Temperatures of Aqueous Monodethanolamine Solutions at 760 mm Hg Absolute



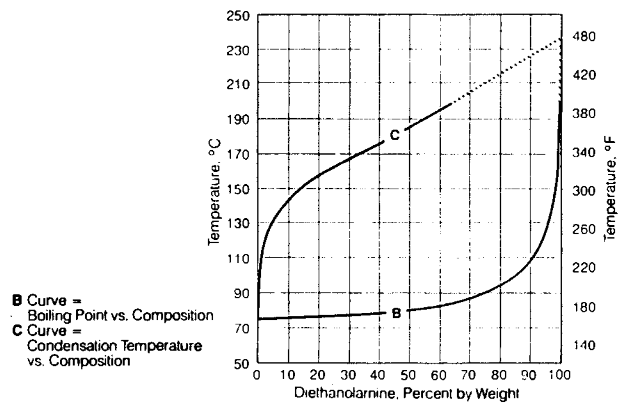
Boiling Points and Condensation Temperatures of Aqueous Monoethanolamine Solutions at 25 psi Absolute



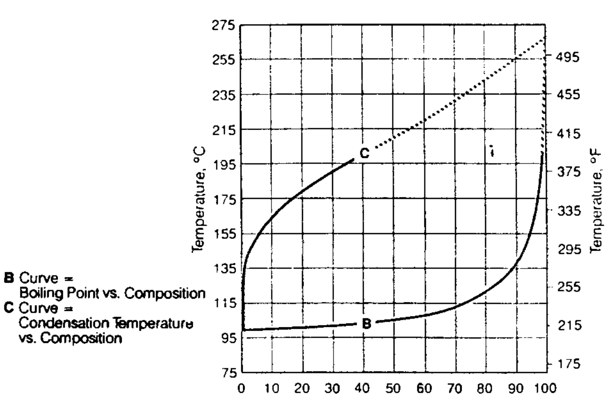
Boiling Points and Condensation Temperatures of Aqueous Diethanolamine Solutions at 50 mm Hg Absolute



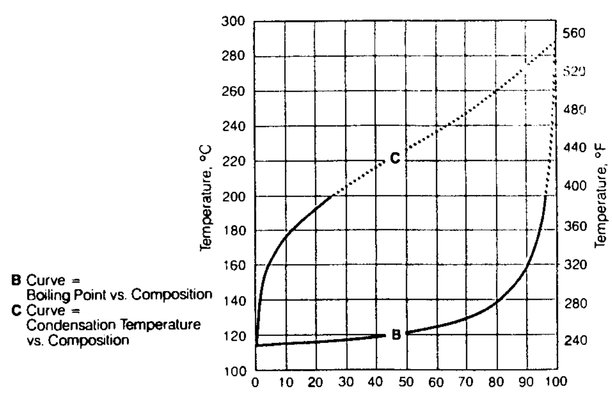
Boiling Points and Condensation Temperatures of Aqueous Diethanolamine Solutions at 300 mm Hg Absolute



Boiling Points and Condensation Temperatures of Aqueous Diethanolamine Solutions at 760 mm Hg Absolute



Boiling Points and Condensation Temperatures of Aqueous Diethanolamine Solutions at 25 psi Absolute

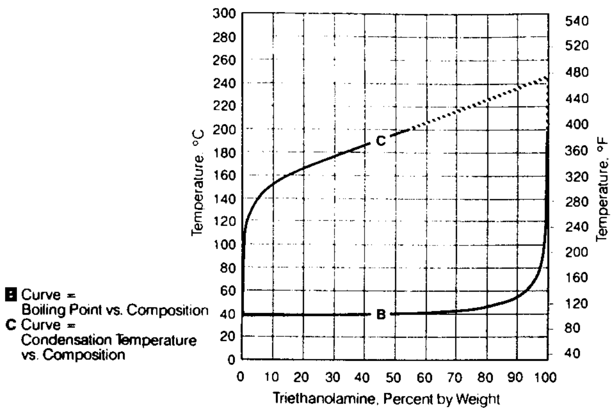


NOTE: Ethanolamines can undergo decomposition reactions at temperatures above 200°C.

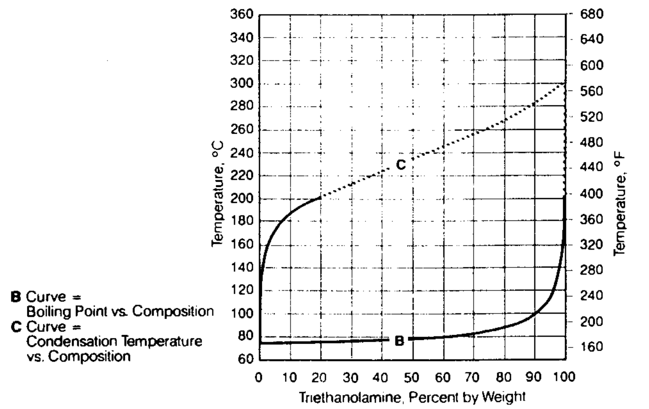
(continued)

Table 14.62: (continued)

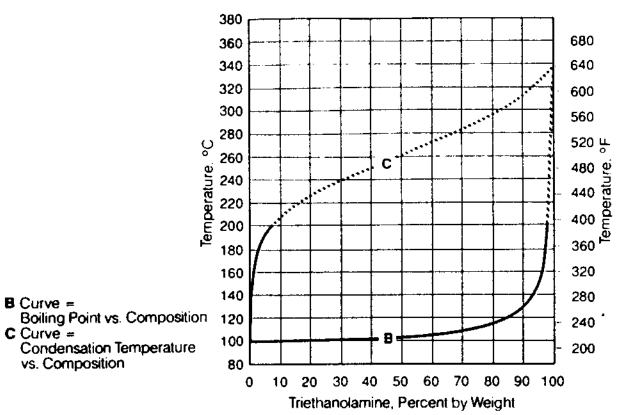
Boiling Points and Condensation Temperatures of Aqueous Triethanolamine Solutions at 50 mm Hg Absolute



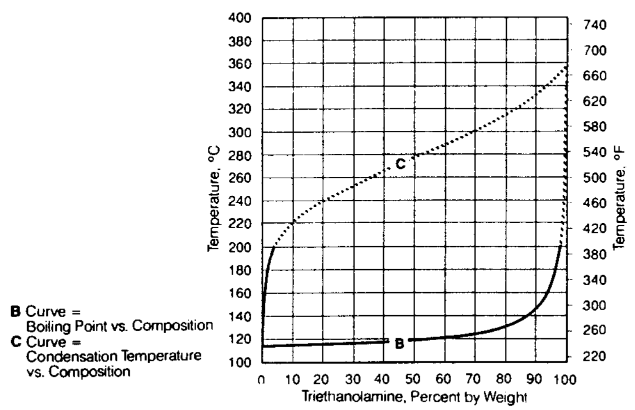
Boiling Points and Condensation Temperatures of Aqueous Triethanolamine Solutions at 300 mm Hg Absolute



Boiling Points and Condensation Temperatures of Aqueous Triethanolamine Solutions at 760 mm Hg Absolute

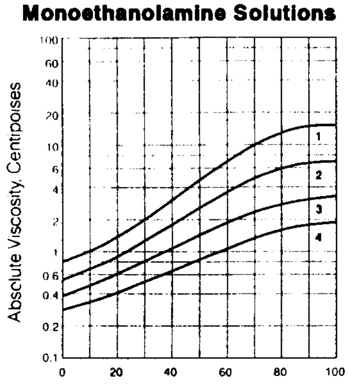


Boiling Points and Condensation Temperatures of Aqueous Triethanolamine Solutions at 25 psi Absolute

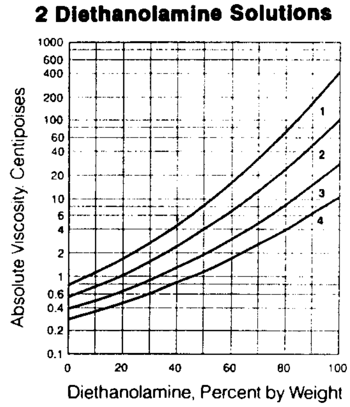


NOTE:
Ethanolamines can undergo decomposition reactions at temperatures above 200°C

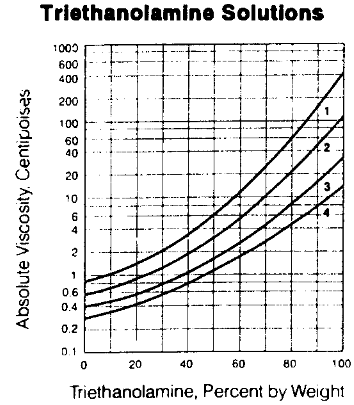
Absolute Viscosity of Aqueous Monoethanolamine Solutions



Absolute Viscosity of Aqueous 2 Diethanolamine Solutions



Absolute Viscosities of Aqueous Triethanolamine Solutions

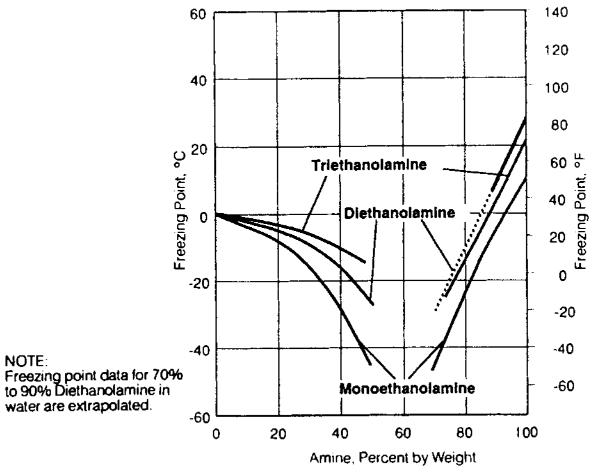


1 30°C (86°F)
2 50°C (122°F)
3 75°C (167°F)
4 100°C (212°F)

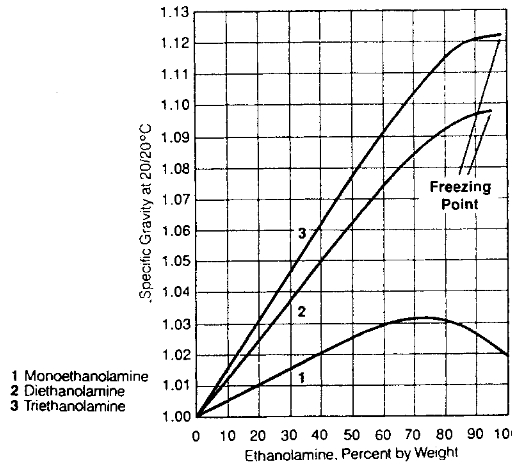
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Table 14.62: (continued)

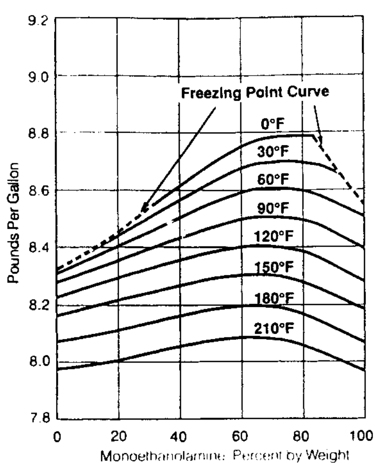
Freezing Points of Aqueous Ethanolamine Solutions



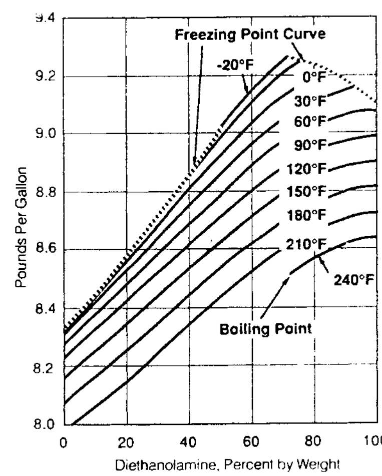
Specific Gravity of Aqueous Ethanolamine Solutions at 20°/20°C



Weight per Gallon of Aqueous Monoethanolamine Solutions at Various Temperatures



Weight per Gallon of Aqueous Diethanolamine Solutions at Various Temperatures



Weight per Gallon of Aqueous Triethanolamine Solutions at Various Temperatures

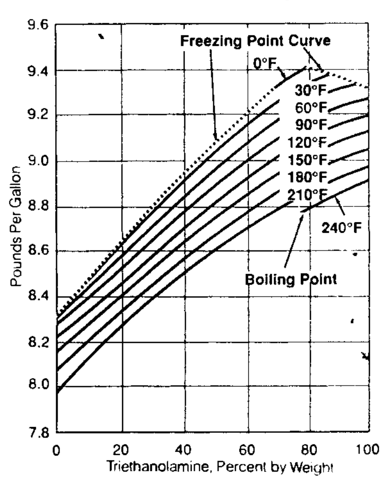
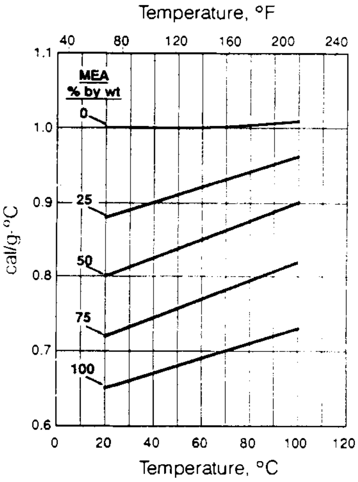
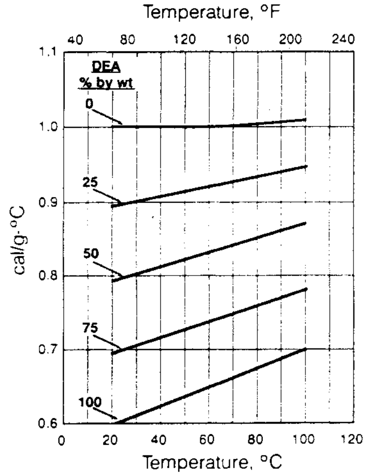


Table 14.62: (continued)

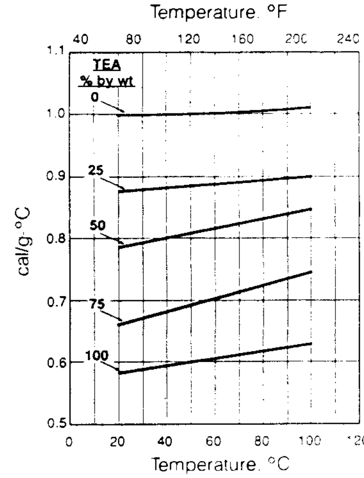
Specific Heats of Aqueous Monoethanolamine Solutions



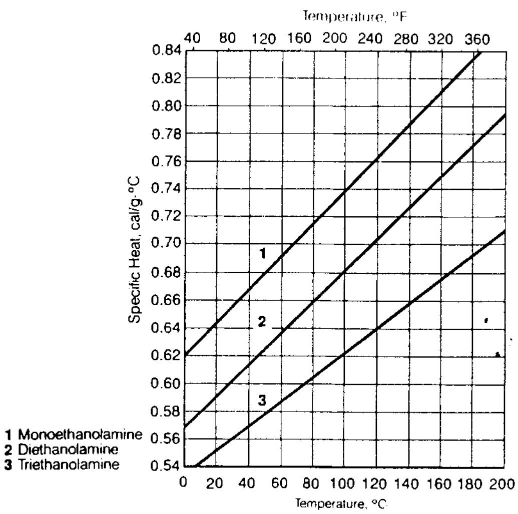
Specific Heats of Aqueous Diethanolamine Solutions



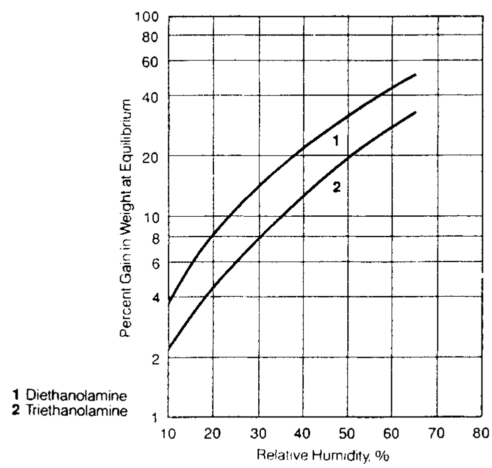
Specific Heats of Aqueous Triethanolamine Solutions



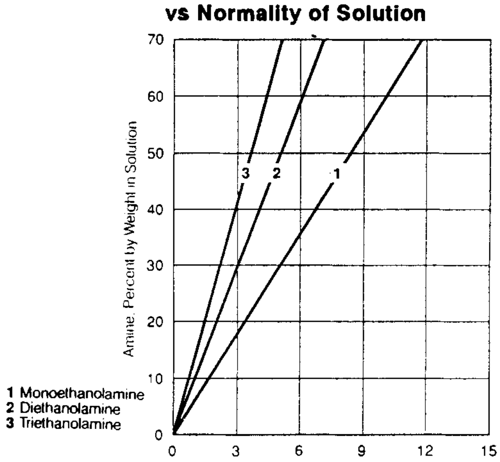
Specific Heat-Temperature Data for Ethanolamines



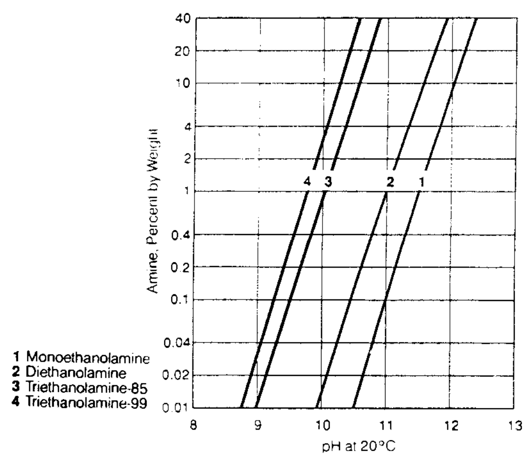
Comparative Hygroscopicities of Diethanolamine and Triethanolamine from 75° to 80°C



Weight Percent Ethanolamine in Aqueous Solutions vs Normality of Solution



pH of Ethanolamines Solutions



ALKANOL AMINES

The most important members of this group from a commercial standpoint are monoethanolamine, diethanolamine, and triethanolamine. Also available in commercial quantities are the aminohydroxy derivatives of nitroparaffins, which are 2-amino-1-butanol, 2-amino-2-methyl-1-propanol, 2-amino-2-methyl-1,3-propanediol, 2-amino-2-ethyl-1,3-propanediol, and tris(hydroxymethyl)aminomethane.

These compounds are used as emulsifiers for cosmetic lotions and creams, mineral oil and paraffin wax emulsions, textiles, leather dressings, cleaning compounds, polishes, and "soluble oils." They are also used in the manufacture of pharmaceuticals, surface-active and wetting agents, vulcanization accelerators, photographic developers, dyestuffs, and resins. Having the property of absorbing acidic gases, such as H_2S and CO_2 in cold aqueous solutions and releasing them when hot, these compounds suggest usefulness in gas recovery and purification. They also form the basis for chemical synthesis.

Table 14.63: Monoethanolamine *(19)*

2(Hydroxyethyl)amine
2-Aminoethanol
Colamine

$H_2NCH_2CH_2OH$

Monoethanolamine is a somewhat viscous hygroscopic liquid with an ammoniacal odor. It is miscible with water and many organic solvents. Its molecule contains both a hydroxyl and an amine group, thus producing derivatives that have characteristics of both types of compounds. It is used as a softener and conditioning agent, and in the recovery and extraction of carbon dioxide and hydrogen sulfide from industrial gases. Its soaps with fatty acids are excellent emulsifiers for waxes. It is also utilized as an intermediate in the manufacture of rubber accelerators and dyestuffs.

Typical Properties and Specifications

Boiling point	172.2°C
Coefficient of expansion at 20°C	0.000770 (per°C)
Dissociation constant at 20°C	5×10^{-5}
Equivalent weight	61 to 63
Flash point (open cup)	93°C (200°F)
Heat of evaporization at B.P.	199 cal/g
Refractive index at 20°C	1.4539
Specific gravity at 20 (20°C	1.0180
Specific heat at 30°C	0.665 cal/g
Surface tension at 20°C	51 dynes/cm
Viscosity at 20°C	3.40 poises
Vapor pressure at 20°C	0.67 mm Hg
Weight per gallon at 20°C	8.472 lbs
Boiling range at 760 mm	Not less than 90% over between 165 and 173°C
Color	Water-white
pH 25% Solution at 25°C	12.1
Solubility in water	Complete

Table 14.64: Boiling Point Composition Curves for Aqueous Monoethanolamine Solutions *(19)*

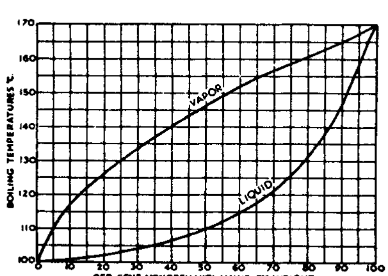


Table 14.65: Viscosity of Monoethanolamine at Various Temperatures *(19)*

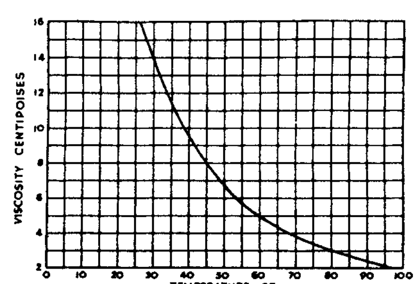


Table 14.66: Diethanolamine *(2)*

Di-2-Hydroxyethylamine $(HOCH_2CH_2)_2NH$

When pure, diethanolamine is a crystalline, white solid which has a melting point of 28°C., or just above room temperature. The commercial material has a mild, ammoniacal odor. Like other ethanolamines, diethanolamine enters into reactions characteristic of both amines and alcohols; its most important property is its ability to combine directly with acids and acidic gases. At normal temperatures, its aqueous solutions have a strong affinity for hydrogen sulfide and carbon dioxide; and at higher temperatures, this affinity decreases, with expulsion of the gases.

Diethanolamine finds wide use as an absorbent for acidic gases; especially for the removal, recovery, and concentration of carbon dioxide from flue and other waste gases as well as from hydrogen gas produced by cracking methane. Many industrial processes require pure hydrogen free of acidic gases. Diethanolamine is used to remove troublesome hydrogen sulfide from sour natural gas in transmission lines and natural gasoline plants. It is also used as a softening, moistening, and emulsifying agent; and in the synthesis of organic compounds by esterification of its hydroxyl groups.

It is an excellent agent for neutralizing the acidity which is developed by the high percentage of clays used in rubber compounding, and thus reduces the curing time considerably. It is also used in the production of powerful synthetic detergents and in certain synthetic resins.

Color and properties: Faintly colored, viscous liquid.
Constants: Sp.gr. 1.0985 at 20°C./20°C.; b. p. (760 mm.) 268.0°C.; vapor pressure < 0.01 mm. (20°C.); flash point 280°F.; wt. 91. lbs./gal. (20°C.). *Typical specifications:* Sp.gr. 1.088 to 1.095 at 30°C./20°C.; water not more than 1.5%; monoethanolamine not more than 2%; diethanolamine not less than 95%; triethanolamine not more than 2%; color (100-mm. tube) not more than 3 yellow and 1 red Lovibond; equivalent wt. 104 to 108; average wt. 9.08 lbs./gal. (30°C.).
Miscible with water and most organic solvents.

Table 14.67: Viscosity of Diethanolamine at Various Temperatures *(19)*

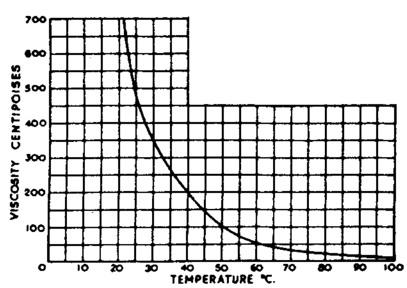


Table 14.68: Triethanolamine *(2)*

Tri-2-Hydroxyethylamine $(HOCH_2CH_2)_3N$

Triethanolamine is a viscous and very hygroscopic liquid with a slight ammoniacal odor. It boils at 244°C. at 50 mm. (360°C. at 760 mm.) and is entirely soluble in water and alcohols, but only slightly soluble in hydrocarbons. It is a mild, organic base which like ammonia combines with acids and acidic materials. The alkalinity of pure triethanolamine is somewhat less than that of ammonia, its pH being 11.2 in 25% solution.

Three commercial grades of triethanolamine are available: 98%, "regular", and "SP." These differ only slightly in physical and chemical properties from the pure compound. The most significant variation is in equivalent weights. Pure triethanolamine has an equivalent weight of 149; "regular," 140; and "SP," about 130. This variation is due to increasing amounts of mono- and diethanolamine present in the respective commercial grades. (continued)

Table 14.68: (continued)

With free fatty acids, triethanolamine forms soaps in direct malecular proportions. Triethanolamine oleate is a semi-liquid soap capable of forming solutions of marked detergent properties in water or in organic solvents such as gasoline. In water, triethanolamine oleate is soluble in all proportions; in gasoline, more than 2% soap is necessary to effect solution. The stearate is a hard, white product which finds use in cosmetic preparations. Only the 98% or regular grades should be used in cosmetic products. These soaps are practically neutral, their pH being approximately 8, and are thus free from irritating effect upon the skin or from injurious effect on fabrics. Very stable water emulsions of almost any oil, fat, or wax can in general be prepared with these soaps. The usual requirements for emulsification are between 2 and 4% triethanolamine and 5 to 15% oleic or stearic acid, each based on the weight of the oil to be emulsified. Triethanolamine emulsions are distinguished by their small particle size, non-corrosiveness, non-volatility, ease of preparation, and wide flexibility in formulation with fear of separation.

A small percentage of triethanolamine assists in the penetration of liquids into porous materials. Because of its pronounced hygroscopicity, it is employed as an economical softening agent, humectant, and plasticizing agent for such products as textiles, glues, leather coatings, as a penetrating agent in impregnating wood, paper, and cellulose products. Also, an ingredient of adhesives, rubber mixtures, and lacquers.

Viscous, pale yellow liquid intermediate in properties between alcohol and ammonia; slightly ammoniacal odor; excellent penetrating properties; forms soaps with fatty acids; hygroscopic. Commercial product contains 70-75% *triethanolamine*, 20-25% diethanolamine, 0-5% monoethanolamine. Soluble in water, alcohol and chloroform. Sp.gr. 1.1204-1.1284; b.p. 360°C; vapor pressure $<$ 0.01 mm (20°C); flash point 355°F; wt./gal. 9.4 lbs. (20°C); coefficient of expansion 0.00048 (20°C); freezing point 21.2°C; viscosity 0.10 poise (20°C).

Typical specifications: Sp. gr. 1.1240-1.1300 (20/20°C); water not more than 1.0%; purity not more than 2.5% monoethanolamine, not more than 15% diethanolamine, not less than 80% triethanolamine; equivalent wt. 140-145; color (500-mm. tube) not more than 7 *yellow* and 2 *red Lovibond*; average wt./gal. 9.40 lbs. (20°C).

Table 14.69: Viscosity of Triethanolamine at Various Temperatures *(19)*

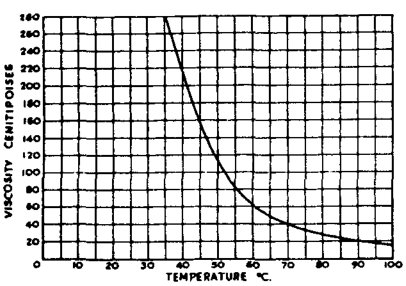


Table 14.70: Specific Heats of Aqueous Triethanolamine Solutions at 21°C *(19)*

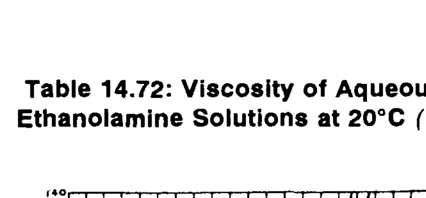


Table 14.71: Surface Tension of Aqueous Ethanolamine Solutions at 20°C *(19)*

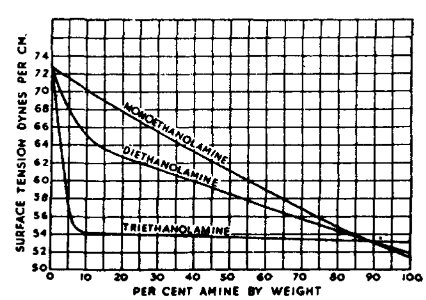


Table 14.72: Viscosity of Aqueous Ethanolamine Solutions at 20°C *(19)*

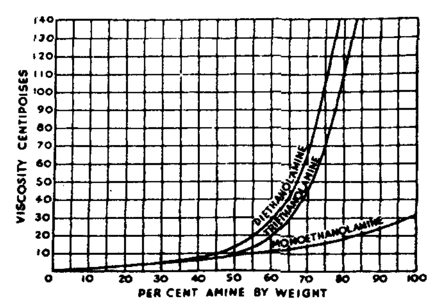


Table 14.73: Isopropanolamines Mixed *(2)*

The mixed isopropanolamines are available as a liquid mixture of mono-, di-, and triisopropanolamine.

Uses: The isopropanolamine soaps may be employed in all uses now found for the ethanolamine soaps. Their excellent hydrocarbon solubility and color stability make them of special interest in soluble oils, dry cleaning soaps, cosmetics, and pharmaceutical preparations. Vinyl acetate resin emulsions of the oil-in-water type for coating fabrics and leather have excellent stability when prepared by stirring 80 parts by weight of "Vinylite" resin AYAF (30% solution in toluene) and 1 part oleic acid, into 20 parts of water containing 0.6 to 0.8 parts of mixed isopropanolamine.

Kerosene solubilized with 4% by weight of mixed isopropanolamine and 15% by weight of oleic acid produces stable emulsions with water upon mechanical agitation. Stable water emulsions of chlorinated hydrocarbons or naphtha may be prepared by a similar procedure. The addition of about 2% by weight of mixed isopropanolamine has been found to improve the penetration of starch glues into heavily sized envelope stock.

Purity	
Monoisopropanolamine	14± 2% by wt.
Diisopropanolamine	43± 4% by wt.
Triisopropanolamine	43+ 4% by wt.
Specific gravity at 20/20°C	1.0040-1.0100

Table 14.74: Triisopropanolamine *(2)*

Tri-2-Hydroxyisopropylamine $(CH_3CHOHCH_2)_3N$

This compound is a white, crystalline solid, completely soluble in water. It is used as a reactant in pharmaceutical syntheses. It is important in the oral treatment of syphilis. Combined with sodium bismuthate and propylene glycol, it produces a bismuth compound stable enough to withstand chemical action of the digestive system. Triisopropanolamine can be used for the preparation of cosmetic creams, "soluble" oils, and emulsions—where the good color stability of its soaps is of interest. Formulas containing lanolin may vary in color stability. Triisopropanolamine is especially suggested for "soluble" white paraffin oils for the rayon industry, where good color and low free fatty acid content are desirable.

Boiling point (760 mm)	305.4°C
Flash point	305°F
Latent heat of vaporization	45°C
Melting point	46°C
pH 25% Solution at 25°C	10.7
Equivalent weight	188-192
Specific gravity at 50/20°C	0.9996
Solubility in water at 20°C	Complete
Solubility of water in amine	Complete
Vapor pressure at 20°C	0.01 mm Hg
Weight per gallon at 50°C	8.32 lbs.

Table 14.75: 2-Amino-2-Methyl-1-Propanol *(2)*

$$CH_3C(CH_3)NH_2CH_2OH$$

This is a water-white, syrupy, alkaline liquid, with a faint ammoniacal odor. It is soluble in water and many organic solvents. It forms soaps with higher fatty acids and these are useful as emulsifying agents in textile and leather materials, water-emulsion paints, and self-polishing waxes.

Boiling point (760 mm)	165°C
Melting point	25°C
Specificity gravity	0.934
pH (0.1 *M* solution at 20°C	11.27
Solubility in 100 cc water	Complete
Vapor pressure at 20°C	1.0 mm
Flash point (Tag. open cup)	153°F
Refractive index at 20°C	1.449
Weight per Gallon at 68°F	7.77 lbs

Table 14.76: 2-Amino-2-Methyl-1,2-Propanediol *(2)*

$CH_2OHC(CH_3)NH_2CH_2OH$

Boiling point at 10 mm	151°C
Melting point	109-111°C
pH (0.1 *M* solution) at 20°C	10.78
Solubility in 100 cc water	250 grams

Table 14.77: 2-Amino-2-Ethyl-1,3-Propanediol *(2)*

$CH_2OHC(C_2H_5)NH_2CH_2OH$

Boiling point at 10 mm	153°C
Flash point (Tag. open cup)	166°F
Melting point	37.5 to 38.5°C
pH of 0.17 *M* aqueous solution at 20°C	10.8
Solubility in water at 20°C	Complete
Specific gravity at 20/20°C	1.099
Refractive index at 20°C	1.490
Weight per gallon at 68°F	9.15 lbs.

Table 14.78: 2-Amino-1-Butanol *(2)*

NH_2
|
$CH_3CH_2CHCH_2OH$

Boiling point at 760 mm	178°C
Flash point (Tag. open cup)	164°F
Melting point	−2°C
pH of 0.1*M* aqueous solution at 20°C	11.1
Specific gravity at 20°/20°C	0.944
Solubility in water at 20°C	Completely Miscible
Vapor pressure at 20°C (est)	0.5 mm
Refractive index at 20°C	1.453

Table 14.79: Tris(Hydroxymethyl)Aminomethane *(2)*

NH_2
|
$CH_2OH-CCH_2OH$
|
CH_2OH

Boiling point at 10 mm	219 to 220°C
Melting point	171 to 172°C
pH of 0.1*M* aqueous solution at 20°C	10.4
Solubility in water at 20°C	80 grams per 100 ml

Table 14.80: 2-Aminoethylethanolamine *(2)*

Hydroxyethyl Ethylenediamine

$NH_2CH_2CH_2NHCH_2CH_2OH$

This compound is a hygroscopic liquid with a mild ammoniacal odor; it is completely soluble in water. It is used in the manufacture of dyes, pharmaceuticals, textile specialties, flotation agents, resins, insecticides, and rubber products.

Boiling point at 760 mm	243.7°C
Flash point	275°C
Specific gravity at 20/20°C	1.0304
Solubility in water	Complete
Solubility of water in solvent	Complete
Vapor pressure at 20°C	0.02 mm Hg
Weight per gallon at 20°C	8.58 lbs.
Boiling range at 760 mm	232-250°C
Purity	99%, min

Table 14.81: 1-Diethylamino-2,3-Propanediol *(2)*

$(C_2H_5)_2NCH_2CHOHCH_2OH$

This alkylol amine is o water-white to light-straw liquid with a faintly ammoniacal odor. It is soluble in water, methyl alcohol, ethyl ether, ethyl, acetate, acetone, aromatic hydrocarbons, fixed oils, oleic and hot stearic acids, and hot carnauba wax, the latter solidifying when cooled. It is insoluble in mineral oil and paraffin wax.

Boiling range	233-235°C
Flash point	210°F
Specific gravity at 20/20°C	0.973

Table 14.82: Aminohydroxy Compounds *(34)*

Product Specifications

	2-Amino-2-methyl-1-propanol		2-Amino-2-ethyl-1,3-propanediol	Tris(hydroxymethyl)aminomethane	
	AMP Regular	AMP-95	AEPD	TRIS AMINO Crystals	TRIS AMINO 40% Concentrate
Neutral equivalent	88.5-91	93-97	121.5*	121-122	—
Water, % by wt (max.)	0.8	5.8	3.8	0.5	—
Melting point, °C (min.)	—	—	—	160	—
Color (max.)	20 APHA	20 APHA	2 Gardner	—	5 Gardner
Color of 20% aqueous solution (max.)	—	—	—	40 APHA	—
Distillation range, °C	156-177	—	—	—	—
Nonvolatile matter, % by wt (max.)	0.005	0.005	—	—	—
Amine assay by titration, calc. as % TRIS AMINO	—	—	—	—	40 ± 2

*Anhydrous basis (max.)

Physical Properties of Purified Materials

	2-Amino-2-methyl-1-propanol	2-Amino-2-ethyl-1,3-propanediol	Tris(hydroxymethyl)-aminomethane
Formula	$CH_3C(NH_2)(CH_3)CH_2OH$	$HOCH_2C(NH_2)(C_2H_5)CH_2OH$	$HOCH_2C(NH_2)(CH_2OH)CH_2OH$
Molecular weight (calcd.)	89.14	119.17	121.14
Boiling point at 760 mmHg, °C	165	—	—
Boiling point at 10 mmHg, °C	—	152-153	219-220
Melting point, °C	30-31	37.5-38.5	171-172
Specific gravity at 40/40°C	0.928	1.101	—
pH of 0.1*M* aqueous solution at 20°C	11.3	10.8	10.4
Solubility in water at 20°C, g/100 ml	miscible	miscible	80
Weight per gallon at 20°C, lb	7.78	9.15	—
pK_a at 25°C	9.72	8.80	8.03

Additional Properties of AMP

	AMP Regular	AMP-95
Viscosity at 10°C, cp	—	561
25°C, cp	—	147
30°C, cp	102	—
50°C, cp	24	—
70°C, cp	9	—
90°C, cp	4	—
Vapor pressure at 100°C, mmHg	59	—
150°C, mmHg	457	—
Specific gravity at 25/25°C	—	0.942
Coefficient of expansion per °C	0.00095	0.00098
Refractive index, n_D, at 20°C	1.449	—
Heat of vaporization at 110°C, kcal/mole	13.2	—
130°C, kcal/mole	12.5	—
150°C, kcal/mole	12.3	—
165°C, kcal/mole	12.1	—
Heat of dissociation at 25°C, kcal/mole	12.9	—

Table 14.83: 2-Diethylamino-2-Methyl-1-Propanol *(34)*

DMAMP-80

$CH_3-C(CH_3)(N(CH_3)_2)-CH_2OH$

Specifications

DMAMP, % by wt (as titratable amine)	78-82
Color, APHA	100 max.
Water, % by wt	18-22

Typical Properties

	DMAMP-80
Neutral equivalent	~148
Specific gravity at 25/25°C	0.95
Weight per gallon at 25°C	7.9 lb
Flash point, Tag open cup	150°F
Tag closed cup	153°F
Freezing point	−20°C
Boiling point at 760 mmHg	~98°C
Viscosity at 25°C, Gardner	$A-A_1$
pH of 0.1 *N* aqueous solution	11.6
APHA color (max.)	100

ALKYLALKANOL AMINES

This group of compounds, also referred to as alkylaminoethanols, have less odor than most alkylamines and possess both water and oil solubility. The solubility degree of each is determined by the number of alkyl or hydroxyl groups present in the molecule. A larger number of hydroxyl groups gives greater water solubility, whereas a predominance of alkyl groups gives greater oil solubility. The derivatives of these compounds are of particular interest. They form soaps with fatty acids which may be employed as emulsifying, penetrating, and wetting agents, and these uses can also be applied to the ester and acid amide derivatives. These amines also serve as intermediates in the manufacture of drugs and dyes.

Table 14.84: Properties of Various Alkylalkanol Amines (2)

Dimethylethanolamine [$(CH_3)_2NCH_2CH_2OH$]. Dimethylethanolamine is a water-white liquid with an amine odor. It resembles diethylethanolamine in chemical behavior and it is used as an intermediate in the synthesis of corrosion inhibitors, dyes, pharmaceuticals, and textile auxiliaries.

Boiling point	133°C
Equivalent weight	89
Specific Gravity at 20/20°C	0.887
Refractive index	1.4300

Diethylethanolamine (Diethylaminoethanol, $(C_2H_5)_2NC_2H_4OH$). Diethylaminoethanol is a water-white, hygroscopic liquid which behaves chemically like the tertiary amines and alcohols. It is soluble in water, ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic hydrocarbons, fixed oils, mineral oil, oleic acid, hot stearic acid, and hot paraffin and carnauba waxes, the last two solidifying when cooled. It is used in the manufacture of certain pharmaceuticals, such as procaine and "atabrine". It forms amine soaps with higher fatty acids, which are oil-soluble and useful as emulsifiers and textile lubricants. Its mild alkalinity makes it applicable as a neutralizing agent and a corrosion inhibitor.

Di-n-butylethanolamine (Di-*n*-Butylaminoethanol, $(C_4H_9)_2NCH_2CH_2OH$). This alkylolamine is a water-white liquid with a faintly amine odor. It is insoluble in water but soluble in ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, aromatic hydrocarbons, fixed oils, mineral oil, oleic and hot stearic acids, and hot paraffin and carnauba waxes, the latter two solidifying when cooled. It is slightly soluble in paraffinic hydrocarbons.

n-Butyl diethanolamine [$C_4H_9N(CH_2CH_2OH)_2$]. This alkylol amine is a light straw-colored liquid with a faintly amine odor. It is soluble in water, ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic hydrocarbons, castor oil, oleic and hot stearic acids, and hot carnauba wax, the latter solidifying when cooled. It is insoluble in linseed and cottonseed oils, mineral oil, and paraffin wax.

***n*-Butyl monoethanolamine** ($C_4H_9NHCH_2CH_2OH$). This alkylol amine is a water-white liquid with a faintly amine odor. It is soluble in water, ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic hydrocarbons, fixed oils, oleic and stearic acids, and hot carnauba and paraffin waxes, the latter two solidifying when cooled. It is only slightly soluble in paraffinic hydrocarbons.

Ethyl diethanolamine [$C_2H_5N(CH_2CH_2OH)_2$]. Ethyl diethanolamine is a water-white liquid with an amine odor and soluble in water, ethyl alcohol, methyl alcohol, acetone, aromatic hydrocarbons, some fixed oils, oleic and hot stearic acids. It is insoluble in linseed and cottonseed oils, mineral oil, paraffin and carnauba waxes. It is only slightly soluble in paraffinic hydrocarbons.

(continued)

Table 14.84: (continued)

Ethyl monoethanolamine ($C_2H_5NHCH_2CH_2OH$). This alkylolamine is a colorless liquid, with an amine odor. It is soluble in water, ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic hydrocarbons, fixed oils, mineral oil, oleic and stearic acids, and hot carnauba and paraffin waxes, the latter two solidifying when cooled. It is only slightly soluble in paraffinic hydrocarbons.

Tetraethanolammonium hydroxide [$N(C_2H_4OH)_4OH$]. This solvent is a white, crystalline, strongly basic solid, completely miscible with water. The commercial product is an aqueous methanol solution in which 40 to 41 per cent of this solvent is present. Although aqueous solutions of this solvent are stable at ordinary temperatures, it will decompose when heated to weakly basic tertiary amines. This property is utilized in processes where it is desired to destroy a strongly alkaline substance which is no longer needed. Tetraethanolammonium hydroxide is also a good solvent for certain types of dyes.

Color	White
Description	Crystalline solid
Melting point	123°C
Solubility in water	Complete
Solubility of water in solvent	Complete
Vapor pressure at 20°C	0.01 mm

	Diethylamino-ethanol	Ethyl Monoethanolamine	Ethyl Diethanolamine
Color	Water-white	Water-white	Water-white
Specific gravity at 20°/20°C.	0.88–0.89	0.92	1.02
Minimum amine content	99.5%	98.5%	98.5%
Initial boiling point	158°C.	161°C	245°C.
Final boiling point	163°C.	174.5°C.	260°C.
Flash point	135°F.	160°F.	255°F.
Solidification point	< −70°C.	−8.8°C.	−50°C.
Refractive index at 20°C.	1.440	1.444	1.466
Viscosity at 25°C (centipoise)	4.05	12.40	53
Viscosity at 60°C (centipoise)	1.50	3.22	11.2
Coefficient of expansion per °C.	0.0012	0.00091	0.00080
Theoretical molecular weight	117.19	89.14	133.19
Average weight per gallon	7.36 lbs.	7.66 lbs.	8.5 lbs.

	Di-n-Butyl-aminoethanol	n-Butyl-Monoethanolamine	n-Butyl Diethanolamine
Color	Water-white	Water-white	Water-white to Light Straw
Specific gravity at 20°/20°C.	0.860	0.89	0.97
Minimum amine content	98.5%	96.0%	95.0%
Initial boiling point	222°C.	192°C.	262°C.
Final boiling point	234°C.	215°C.	290°C.
Flash point	200°F.	170°F.	245°F.
Solidification point	< −70°C.	−3.5°C.	< −70°C.
Refractive index at 20°C.	1.444	1.444	1.462
Viscosity at 25°C (centipoise)	6.50	17.4	55
Viscosity at 60°C (centipoise)	1.94	4.02	10.6
Coefficient of expansion per °C.	0.00114	0.0010	0.00077
Theoretical molecular weight	173.29	117.19	161.24
Average weight per gallon	7.16 lbs.	7.44 lbs.	7.25 lbs.

GLYCOL ETHER AMINES

Table 14.85: Properties of Various Glycol Ether Amines *(47)*

Amine	Methoxyethyl	Dimethoxyethyl	Ethoxyethyl	Diethoxyethyl	Methoxyisopropyl
Formula	$CH_3OC_2H_4NH_2$	$(CH_3OC_2H_4)_2NH$	$C_2H_5OC_2H_4NH_2$	$(C_2H_5OC_2H_4)_2NH$	$CH_3OCH_2CH(CH_3)NH_2$
Molecular Weight	75	133	89	161	89
Boiling Point, °C.	91	172	107	194	98
Vapor Pressure, mm. at 20°C.	--	1.0	--	0.5	--
n_D at 25°C.	1.4058	1.4190	1.4086	1.4205	1.4038
Specific Gravity	0.89	0.91	0.85	0.88	0.84
pK_b	4.62	5.49	7.74	5.53	4.60
Flash Point, °F.	60	155	70	185	60

Formula	$(C_4H_9)_2NH$	$(CH_3OCH_2CH_2)_2NH$	$(HOCH_2CH_2)_2NH$
Molecular Weight	129	133	105
Boiling Point, °C.	160	172	270
Vapor Pressure, (20°C.)	1.9	1.0	<0.01
Freezing Point, °C.	-62	<-40	28.0
Specific Gravity	0.76	0.91	1.09
pK_b	2.7	5.5	5.2
% Solubility in H_2O at 25°C.	0.47	∞	∞

Formula	$C_4H_9CH(C_2H_5)CH_2NH_2$	$CH_3OCH_2CH(CH_3)O$-$CH_2CH(CH_3)NH_2$
Molecular Weight	129	147
Boiling Point, °C.	169	175
Vapor Pressure, (20°C.)	1.2	1.0
Freezing Point, °C.	--	--
Specific Gravity	0.79	0.85
pK_b	3.2	4.8
% Solubility in H_2O at 25°C.	0.25	∞

ARYL AMINES

Table 14.86: Aniline *(2)*

Aminobenzene
Phenylamine

$C_6H_5NH_2$

Aniline is a colorless to straw-colored, toxic, highly refractive, oily liquid having a characteristic odor. It is soluble in ethyl alcohol, ethyl ether, carbon tetrachloride, and only slightly soluble in water. It is used in the production of such materials as indigo, aniline black, tetranitraniline, acetanilide, explosives, dyes, rubber chemicals, and pharmaceuticals.

Boiling point	184.2°C
Flash point	70°C
Freezing point	−6.3°C min.
Melting point	−6.2°C
Specific gravity at 25/25°C	1.021
Solubility in water at 25°C	3.8
80°C	6.0
Weight per gallon at 25°C	8.50 lbs.
Boiling range	1.5°C
	95% distills within 1.0°C
Nitrobenzene	None

Table 14.87: Dimethylaniline *(2)*

$C_6H_5N(CH_3)_2$

Dimethylaniline is a pale yellow, highly refractive, toxic, oily liquid with a pungent odor. It is soluble in ethyl alcohol, ethyl ether, and carbon tetrachloride, but only very slightly soluble in water. It is used in the making of dyes and the explosive tetranitroaniline ("Tetryl").

Boiling point	192.9°C
Freezing point	1.5°C
Specific gravity at 25/25°C	0.956
Weight per gallon at 25°C	7.95 lbs.
Boiling range within	2.0°C
	95% distills within 1.0°C
Color	Yellow to amber
Monomethylaniline	0.5% max.

Table 14.88: Diethylaniline *(2)*

$C_6H_5N(C_2H_5)_2$

Diethylaniline is a light-yellow, oily, toxic liquid with a pungent odor. It is soluble in ethyl alcohol, ethyl ether, and carbon tetrachloride, but only very slightly soluble in water. It is used in the preparation of dyes, pharmaceuticals, and other organic compounds.

Boiling range	216.3°C
Freezing point	−34.4°C
Specific gravity at 25/25°C	0.933
Weight per gallon at 25°C	7.76 lbs.
Aniline	None
Boiling range	5–95% within 2.5°C
	Boiling range includes 216.3°C
Color	Light yellow
Monoethylaniline	0.2% max.
Purity	99.8%, min.
Water	No visible separation

Table 14.89: N-Mono-n-Butyl Aniline *(2)*

$C_6H_5NHC_4H_9$

This secondary amine is a light straw to amber-colored liquid with an aniline odor. It is insoluble in water but soluble in ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic acid, and hot stearic acid. It is also soluble in hot paraffin and carnauba waxes which solidify upon cooling.

Flash point	225°F
Specific gravity at 20°C	0.93
Refractive index at 20°C	1.5351
Weight per gallon at 20°C	7.71 lbs.
Boiling range	234-242°C
Purity	95%, min.

Table 14.90: N,N-Di-n-Butyl Aniline *(2)*

$C_6H_5N(C_4H_9)_2$

N,N-Di-n-Butyl aniline is a light-straw colored liquid with a faintly aniline odor and is soluble in ethyl alcohol, aromatic hydrocarbons, ethyl ether, ethyl acetate, acetone, fixed oils, mineral oil, oleic acid and hot stearic acid. It is insoluble in water, methyl alcohol, and while soluble in hot paraffin and carnauba waxes, these solidify when cooled.

Flash point	230°F.
Specific gravity at 20°C	0.904
Refractive index at 20°C	1.5197
Weight per gallon at 20°C	7.53 lbs.
Boiling range	267-275°C
Purity	95%, min.

Table 14.91: n-Monoamyl Aniline (Mixed Isomers) *(2)*

$C_6H_5NHC_5H_{11}$

n-Monoamyl aniline is a mixture of isomers. It is a light-straw colored liquid with a faintly aniline odor. It is insoluble in water but soluble in ethyl alcohol, methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic acid, and hot stearic acid. It is also soluble in hot paraffin and carnauba waxes which solidify on cooling.

Flash point	225°F
Specific gravity at 20°C	0.92
Refractive index at 20°C	1.5285
Weight per gallon at 20°C	7.64 lbs.
Boiling range	245-260°C
Purity	95%, min.

Table 14.92: p-tert-Amyl Aniline *(2)*

$C_5H_{11}C_6H_4NH_2$

p-tert-Amyl aniline, an aryl amine, is a straw to deep red-colored liquid with a faintly aromatic odor. It is soluble in methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic acid and hot stearic acid. It is insoluble in water and while it dissolves hot carnauba and paraffin waxes, these solidify on cooling.

Flash point	215°F
Specific gravity at 20/20°C	0.948
Boiling range	253-259°C

Table 14.93: Di-tert-Amyl Aniline *(2)*

$$(C_5H_{11})_2C_6H_3NH_2$$

Di-tert-amyl aniline, an aryl amine, is a red-colored, almost odorless liquid, soluble in ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic acid and hot stearic acid. It is insoluble in water and methyl alcohol, and dissolves hot carnauba and paraffin waxes, which solidify when cooled.

Flash point	265°F
Specific gravity at 20/20°C	0.923
Boiling range	289–321°C

Table 14.94: N,N-Diamyl Aniline (Mixed Isomers) *(2)*

$$C_6H_5N(C_5H_{11})_2$$

N,N-diamyl aniline is a dark-amber liquid with a faintly aniline odor. It is insoluble in methyl alcohol and water, but soluble in ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic acid, and hot stearic acid. It is also soluble in hot carnauba and paraffin waxes, which solidify on cooling.

Flash point	260°F
Specific gravity at 20/20°C	0.898
Boiling range	276–292°C

Table 14.95: Diethylbenzylamine *(2)*

$$C_6H_5CH_2N(C_2H_5)_2$$

Diethylbenzylamine is a colorless liquid with an almond-like odor. It is soluble in ethyl and methyl alcohols, ethyl ether, ethyl acetate, acetone, aromatic hydrocarbons, fixed oils, mineral oil, oleic acid and hot stearic acid. It is insoluble in water and while soluble in hot paraffin and carnauba waxes, these solidify on cooling.

Flash point	170°F
Specific gravity at 20°C	0.890
Refractive index at 20°C	1.5002
Weight per gallon at 20°C	7.41 lbs.
Boiling range	207–215°C
Purity	97%, min.

Table 14.96: N-(n-Butyl)-α-Naphthylamine *(2)*

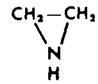
$$C_{10}H_7NHC_4H_9$$

This solvent is a dark-red liquid with a faintly amine odor. It is a solvent for methyl alcohol, ethyl ether, ethyl acetate, acetone, aromatic and aliphatic hydrocarbons, fixed oils, mineral oil, oleic and hot stearic acid. It is insoluble in water, and soluble in hot paraffin and carnauba waxes which solidify on cooling.

Flash point	295°F
Specific gravity at 20/20°C	1.012
Boiling range	318–325°C

IMINES

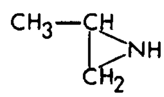
Table 14.97: Ethylene Imine *(23)*



Ethylene imine is a colorless mobile liquid having an amine-like odor, with the above structure.

Molecular Weight	43.07
Density, gm./ml. – 10° C.	0.865
0° C.	0.856
10° C.	0.846
25° C.	0.832
Boiling Point, °C.	57
Freezing Point, °C.	–78
Index of Refraction, n_D at 25° C.	1.4123
Viscosity, cps. at 25° C.	0.418
Surface Tension, dynes/cm.	32.8
Flash Point, °F.	12
Heat of Formation, Kcal./mole	21.95
Heat of Vaporization, Kcal./mole at 20° C.	7.9
Dissociation Constant	7.8×10^{-7}

Table 14.98: Propylene Imine *(41)*



Molecular Weight	57.09
Density, g./ml.	
25°C.	0.8017
35°C.	0.7908
45°C.	0.7811
$\Delta d/\Delta t$, g./ml. per °C. at 25°C.	0.0011
Boiling Point, °C. at 760 mm. Hg	66.0
ΔB.P./Δp, °C. per mm. Hg at 760 mm. Hg	0.038
Vapor Pressure at 25°C., mm. Hg	140
Refractive Index, N_D at 25°C.	1.4084
Absolute Viscosity, centipoises at 25°C.	0.491
pKa at 25°C.	8.18
Heat of Vaporization at 66°C. and 1 atm, cal. per g.	139
Integral Heat of Solution of P.I. in water, 5 wt. % P.I. final conc., kcal./mole	4.5
Heat of Vaporization at 66°C. and 1 atm, BTU per lb.	250
Solubility:	
Water	Soluble in all Proportions
Polar organic solvents	Soluble in all Proportions
Pentane	Soluble in all Proportions

AMIDES

Table 14.99: Formamide *(11)*

$HCONH_2$

Formamide is a water-white to light yellow, hygroscopic liquid. It is miscible in all proportions with the lower alcohols and glycols, but is insoluble in hydrocarbons, chlorinated solvents and ethers. Its high dielectric constant is an indication of its high ionizing power.

Formamide dissolves many metal chlorides, iodides, nitrates, phosphates, and some carbonates and is less soluble in sulfates and oxides. Proteins, saccharides, and polyvinyl alcohol dissolve or soften in formamide. Cellulose will swell in formamide as it does in water. Formamide is a nonaqueous solvent for electrolytes due to its ionizing solvent action on numerous inorganic salts.

AVERAGE ANALYSIS	
Formamide, %	98.5
Methanol, %	1.0
Color (as shipped), APHA	7
PHYSICAL PROPERTIES	
Molecular weight	45.04
Boiling point (760mm), °C	210
°F	410
Freezing point, °C	2.6
°F	36.7
Specific gravity, 25°/4°C (77°/39°F)	1.1339
Density, lb/gal, 60°F (15.6°C)	9.5
Refractive index, N_D^{20}	1.4481
Surface tension, dynes/cm, 20°C (68°F)	58.35
Viscosity, cp, 20°C (68°F)	3.76
Dielectric constant, 20°C (68°F)	84
Solubility parameter	19.2
Hydrogen bonding index	>16.2
Specific conductance, ohm^{-1}, 25°C (77°F)	18.9×10^{-5}
Specific heat of liquid, cal/g, 19°C	0.55
Btu/lb, 66°F	0.99
Latent heat of vaporization, cal/g, 210°C	400
Btu/lb, 410°F	720
Flash point (TOC), °F	310
°C	154.4

Table 14.100: Dimethylformamide *(11)*

DMF $(CH_3)_2NCH{=}O$

DMF, dimethylformanide, is a uniquely versatile and powerful solvent with the following general properties:

Appearance	Colorless, mobile liquid
Molecular weight	73.09
Boiling point, 760mm, °C	153 (307°F)
Freezing point, °C	−61 (−78°F)
Specific gravity 0°/4°C	0.9683
25°/4°C	0.9445
Density, lbs/gal, 20°C	7.92
Refractive index, N_D25°C	1.4269
Vapor pressure, 25°C	3.7mm
Viscosity, 25°C	0.802 cp
Surface tension, 25°C	35.2 dynes/cm
Specific heat (liquid, 20°C)	0.49 Btu/lb/°F
Heat of vaporization	248 Btu/lb
Heat of combustion	457.5 kg cal/gm mol
	11,280 Btu/lb
Thermal conductivity (at 23.5°C)	440 cal/sec cm°C
Flash point, T.O.C., °C	67 (153°F)
Ignition temperature, °C	445 (833°F)
Flammability limits in air	
lower	2.2 vol %
upper	15.2 vol %
Dielectric constant, 25°C	36.71
Dipole moment, 20°C	3.82 Debye Units
Hygroscopicity, 30°C (300 hrs @ 50% RH)	34% gain
Relative evaporation rate (butyl acetate = 100)	17
Solubility parameter	12.1
Ionization constant (@ 20°C)	10^{-18}
Azeotropes:	
DMF (18.7 wt %), p-xylene (81.3%)	135.1°C at 760mm
DMF (69 wt %), formic acid (31 wt %)	162.4°C at 760mm
DMF (7 wt %), tetrachlorethylene (93.0 wt %)	117.5°C at 730mm

(continued)

Table 14.100: (continued)

Evaporation Rate

Atmospheric conditions . . .

% Evaporation	Time, Hours
0	0
20	8
40	16
60	26
80	34
100	44

Heat of Mixing DMF-Water . . .

Temp 30°C . . .

Wt % DMF in Aqueous Solution	Btu/lb DMF
5	89
10	82.5
15	75
20	73.5
25	70
30	66
35	64

Flash and Fire Point of DMF Water Solutions . . .

Composition, DMF-H_2O Mixture—DMF % by Wt	Flash Point °F	Fire Point °F
100	145	150
90	165	170
70	215	230
65	210	225
60	none	none
50	none	none

Table 14.101: Surface Tension and Density of DMF-Water Mixtures *(11)*

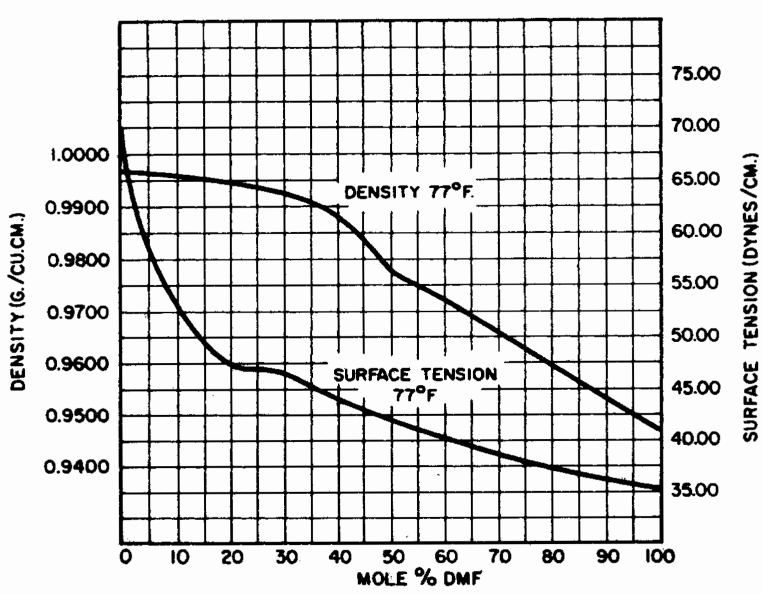


Table 14.102: Semi-Quantitative Solubilities of Inorganic Materials in DMF at 25°C *(11)*

Salt	Solubility g/100g DMF	Salt	Solubility g/100g DMF
AgBr	0.03	LiH	0.7
AgCl	0.01	$MgCl_2$	moderate
AgI	0.04	$MgSO_4$	0.13[95]
$AlCl_3$	reaction	$MnCl_2 \cdot 4H_2O$	15
$Al(NO_3)_3 \cdot 9H_2O$	20	$NaB(OCH_3)_4$	77.8
$Be(NO_3)_2 \cdot 3H_2O$	20	$NaBH_4$	25.5[94]
$CaCl_2$	Approx. 0.5	$NaCHO_2$	0.03
CaF_2	0.05	$NaC_2H_3O_2 \cdot 3H_2O$	1.5
$Ca(NO_3)_2 \cdot 4H_2O$	20	NaCl	0.05
$CaSO_4 \cdot 2H_2O$	1.2[93]	NaCN	0.76
$Cd(NO_3)_2$	20	NaCNO	0.05
$Co(C_2H_3O_2)_2 \cdot 4H_2O$	20	NaCNS	29.2
$CoCl_2 \cdot 6H_2O$	20	Na_2CO_3	0.05
$Co(NO_3)_2 \cdot 6H_2O$	20	$Na_2Cr_2O_7 \cdot 2H_2O$	20
$CoSO_4 \cdot 7H_2O$	slight	$Na_2Fe(CN)_5(NO) \cdot 2H_2O$	25
$CrCl_3 \cdot 6H_2O$	40	Na_2HPO_4	0.05
$Cu(C_2H_3O_2)_2$	slight	NaI	14.4
$CuCl_2 \cdot 2H_2O$	15	$NaIO_3$	0.05
$Cu(NO_3)_2 \cdot 3H_2O$	20	$NaNO_2$	2.0*
$CuSO_4$	1.8	$NaNO_3$	15.4
$FeCl_3$	20	$NaPO_3$	0.05
$Fe(NO_3)_3 \cdot 6H_2O$	20	$Na_2S_2O_3$	0.08
$FeSO_4 \cdot 7H_2O$	slight	NH_4Br	12.7[95]
$HgCl_2$	25	$NH_4C_2H_3O_2$	0.1
I_2	25	NH_4Cl	0.1
KBH_4	1.2	NH_4CNS	15.2
$KC_2H_3O_2$	0.09	$(NH_4)_2CO_3$	0.04
KCl	0.05	NH_4NO_3	55.1
KCN	0.22	$NiCl_2 \cdot 6H_2O$	5
KCNO	0.12	$Ni(NO_3)_2 \cdot 6H_2O$	20
KCNS	18.2	$Pb(C_2H_3O_2)_2 \cdot 3H_2O$	1.5
$K_3Fe(CN)_6$	0.05	$Pb(HCO_2)_2$	0.1
KI	25	PbO	0.3
$KMnO_4$	reaction	PbS	0.15
KNO_2	0.7[92]*	$PbSO_4$	0.1
KNO_3	1.5		
KOH	0.1		
$LiBH_4$	3.5[94]		
LiCl	11.40		

*Urea increases solubility:
4.7g $NaNO_2$ with 4.6g urea
8.1g $NaNO_2$ with 9.3g urea
3.7g KNO_2 with 7.5g urea

Cellulosic	Cellulose nitrate	S
	Cellulose acetate	S
	Cellulose acetate butyrate	S
	Cellulose acetate propionate	S
	Cellulose triacetate	PS
	Ethyl cellulose	S
	Cyanoethylated cellulose	S
Chlorinated Polyether ("Penton"—Hercules Powder)		I
Nylon (polyamides)	Types 6/6, 6, 6/10	I
	Type 8 (Belding-Corticelli Industries, B.C.I.)	S
Polyethylene		I
Polypropylene		I
Polycarbonate	("Lexan"—General Electric Company)	PS
Fluorocarbons	Polytetrafluoroethylene ("Teflon"*)	I
Styrene	Polystyrene	S
	Styrene-acrylonitrile copolymer (Tyril 767—Dow)	S
Vinyl Polymers and Copolymers	Polyvinyl chloride	S
	Polyvinyl chloride-acetate	S
	Polyvinyl alcohol	S
	Polyvinyl butyral ("Butacite"*—DuPont)	S
	Vinylidene chloride/vinyl chloride copolymer (Geon 200 x 20)	S
	Vinylidene chloride/vinyl chloride copolymer (Saran B-115)	I
	Polyvinyl acetate	S
	Polyvinyl formal	S
	Polyvinyl fluoride	S
Polyesters	Saturated ("Mylar"*)	I
	Alkyd	S
Phenolic	Phenol-formaldehyde pure resin	S
	Ester gum modified phenol-formaldehyde	S
	Urea formaldehyde	I
	Thiourea formaldehyde	S
Coumarone	Coumarone-indene	S
Natural	Garnet shellac	S
	Orange shellac	PS
	Ester gum	S
	Kauri gum	S
	Manila copal	S
	Esterified congo copal	I
	Wood resin	S
	Damar	I
	Soft albino asphalt	PS
Epoxy (cured)		I
Polyurethanes		S

(continued)

Table 14.102: (continued)

Polymer Solvent

The principal use of DMF is as a solvent in the spinning of acrylic and polyurethane fibres. This is a specialised outlet but illustrates the solvent power of DMF for polymers of high molecular weight.

Various polymers which are soluble in DMF together with some which are insoluble are shown in the following lists:

Soluble	*Insoluble*
polyacrylonitrile	polyethylene
polyurethanes	polypropylene
polymethylmethacrylate	polytetrafluoroethylene
cellulose acetate	saturated polyesters
cellulose nitrate	urea-formaldehyde resins
cellulose acetate butyrate	natural rubber
ethylcellulose	butyl rubber
cyanoethylated cellulose	styrene-butadiene rubber
polystyrene	nylon 66, 6, and 610
polyvinyl chloride	
polyvinyl alcohol	
polyvinyl acetate	
alkyds	
phenol-formaldehyde resins	
coumarone-indene resins	
shellac	
ester gum	
kauri gum	

Not only does DMF allow many polymers of sparing solubility to be brought into solution at economical concentrations, but when used either alone or as a booster solvent it yields solutions with lower viscosities and higher solids content than can be obtained with other solvents. It is therefore suggested as an attractive solvent for use in the formulation of protective coatings and films, adhesives, and printing inks.

Reaction Solvent and Catalyst

The use of DMF alone or as a component of a solvent system confers a number of advantages, the relative importance of which depends upon the particular application, but the following may be specially noted:

(*a*) its high solvent power can increase the effective concentration of one of the reacting species;

(*b*) it has a high dielectric constant;

Table 14.103: Dimethylacetamide *(11)*

DMAC

PHYSICAL PROPERTIES OF DIMETHYLACETAMIDE:

Formula	$CH_3\overset{O}{\overset{\|}{C}}N(CH_3)_2$
Molecular weight	87.12
Boiling point	165.5°C
Vapor pressure at 25°C	1.3 mm
Freezing point	—20°C
Specific gravity (15.5°C)	0.9448
Pounds per gallon (15.5°C)	7.87
Viscosity (25°)	0.92 cp
Refractive index	1.4356
Dielectric constant	37.8
Dipole moment (in dioxane)	3.79
Flash point (Tag Open Cup)	70°C
Thermal conductivity (22.2°C)	416×10^{-6}cal/sec/cm/°C
Specific heat (liquid, 0 to 87°C)	0.485 BTU/lb°F
Heat of vaporization at 165°C (cal'd)	10,360 cal/g mol
Heat of combustion (20°C)	608 k cal/g mol

Flammability limits in air at 740 mm Hg and 160°C

Lower	2.0% by vol
Upper	11.5% by vol

(continued)

Table 14.103: (continued)

Vapor pressure:—

Temperature, °C	Pressure, mm Hg
25	1.3
40	3.4
70	18
90	46
110	108
130	230
150	460
165.5	758

Azeotrope —
DMAC (77.2 wt %)—acetic acid (21.1 wt %)—170.8°C at 760 mm

Solubility—Completely miscible with water, ethers, esters, ketones, and aromatic compounds. Unsaturated aliphatics are highly soluble, but saturated aliphatics have limited solubility.

	Solubility at 25°C g/100 g DMAC
Iso-octane	33
Di-isobutylene	Compl Misc
N-hexane	" "
N-Heptane	31
Cyclohexane	Compl Misc
Cyclohexene	" "
Kerosene	16

Table 14.104: Viscosities of Resins in DMAC *(11)*

Viscosities of Surface Coating Resins in DMAC

		Viscosity at 25°C, 15 wt % Solution—cps
Acrylic Resins		
Acryloid®[a]	A-21[b]	23
	A-107[b]	23
	B-72[b]	20
Lucite®[c]	44	26
	45	38
	46	30
Expoxy Resins		
Epon®[d]	1001	5
	1002	6
	1004	7
	1007	10
Cellulosic Resins		
Half-Sec. Butyrate		555
EAB-500-1[e]		950
EAB-171-2[e]		1275
Urea-Formaldehyde Resins		
Uformite®[a]	F-222[f]	20
Melamine-Formaldehyde Resin		
MM-55		18

Viscosities of Vinyl Resins in DMAC

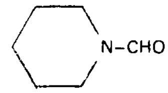
	Viscosity at 25°C, 15 wt % resin in 50/50 Solvent/ Toluene, cps
VYHH[g]	52
VAGH[g]	53
VMCH[g]	48
Geon®[h] 121	230
Geon®[h] 101	3800

Viscosities of Nitrocellulose Solutions in DMAC

	Viscosity at 25°C, 8 wt % resin in Solvent, cps
HB-14 Nitrocellulose[c]	18

(a)—Rohm and Haas Company
(b)—Reduced to 5 wt % solids with DMAC
(c)—E. I. du Pont de Nemours & Co. (Inc.)
(d)—Shell Chemical Corporation
(e)—Eastman Chemical Products, Inc.
(f)—Reduced to 30 wt % solids with DMAC
(g)—Union Carbide Chemicals Company
(h)—B. F. Goodrich Chemicals Company

Table 14.105: 1-Formylpiperidine *(78)*



1-Formylpiperidine, an amide solvent, is a stable, highly ordered, dipolar aprotic liquid having a high boiling point and wide liquid range (-30.6° to 222°C), making this a favorable solvent for nonvolatile applications in gas absorption processes, ink and dye systems, and plastics modifiers and stabilizers. 1-Formylpiperidine is a strong solvent for both polar and nonpolar compounds. It is unusual for its solubility in both water and hexane. It is miscible with acyclic alkanes (C_6 and below), cycloalkanes, alcohols, esters, ketones, aldehydes, amines, carboxylic acids and hydrides, amides, alkyl halides beyond C_{11}, stearates, ethers, olefins, nitriles, nitro compounds, heterocyclics, aromatics, organophosphorus compounds, alkynes, organotin compounds, organosilicates and inorganic acids. The high solubility of many polymers in 1-formylpiperidine is of particular significance. 1-Formylpiperidine is a reactive solvent reacting at the carbonyl center and at the amide nitrogen.

Molecular Formula	$C_6H_{11}NO$
Molecular Weight	113.16
Density	1.02 g/ml (8.51 lb/gal)
Index of Refraction (25.0°C)	1.4823
Freezing Point	-30.6°C
Boiling Point	222°C
Vapor Pressure	
25°C	0.1 mm Hg (0.002 lb/in^2, 0.0001 atm)
100°C	14 mm Hg (0.27 lb/in^2, 0.02 atm)
Heat of Vaporization (ΔHvap)	16.5 kcal/mol (262 Btu/lb)
Heat of Fusion (ΔH_f)	2.2 kcal/mol (35 Btu/lb)
Heat of Sublimation (ΔHsub)	18.7 kcal/mol (297 Btu/lb)
Entropy of Vaporization (ΔSvap)	33.4 cal/°/mol
Molar Freezing Point Depression Constant	5.7°C/mol
Corrosion of Metals at 222°C	
Mild Steel	0.3 x 10^{-4} in/yr
Brass	3.2 x 10^{-4} in/yr
Copper	5.2 x 10^{-4} in/yr
Hydroscopicity (23°C, 100% RH, exposed surface area/volume = 1.67 cm^{-1})	0.16% weight gain/hour (nearly linear to 100 hr)

Solubilities of Gases (g/100 g, 23°C, 1 atm)

Ammonia	1.1
1,3-Butadiene	12.9
1-Butene	6.8
Carbon Dioxide	0.8
Methyl Chloride	12.9
Ethane	0.2
Methane	less than 0.1

Solubilities of Inorganic Solids (g/100 g, 23°C)

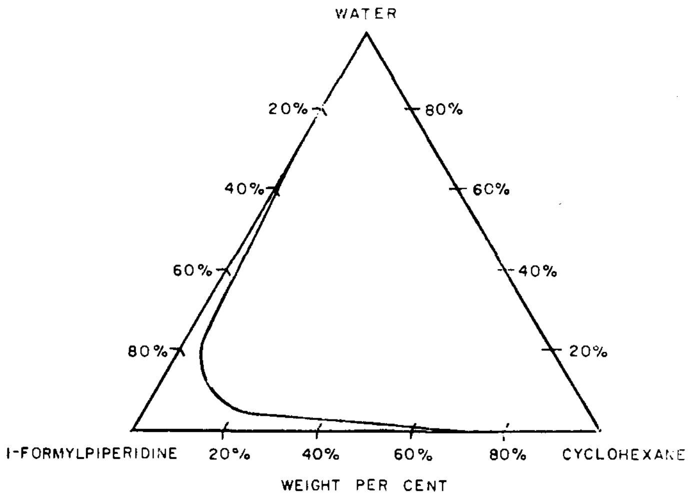
Aluminum Chloride	Reacts
Potassium Acetate	0.51
Potassium Cyanide	0.06
Potassium Iodide	18.9
Potassium Permanganate	Reacts
Sodium Chloride	0.08
Ammonium Bromide	2.4
Sodium Iodide	17.1
Sodium Hydroxide	0.02

Toxicity

LD_{50} in rats and mice (C5)	~1,100 mg/kg of body weight

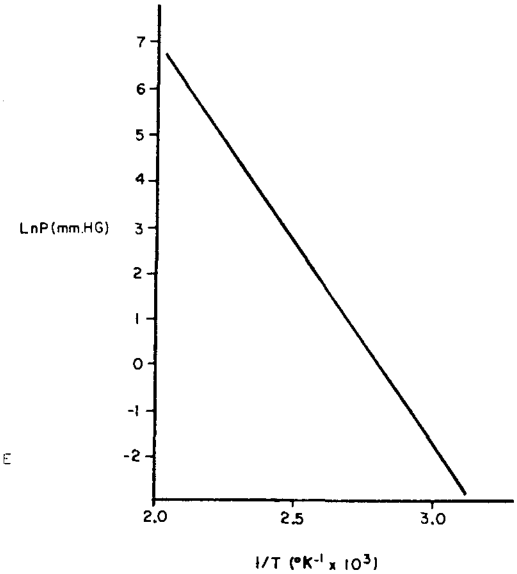
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Table 14.105: (continued)



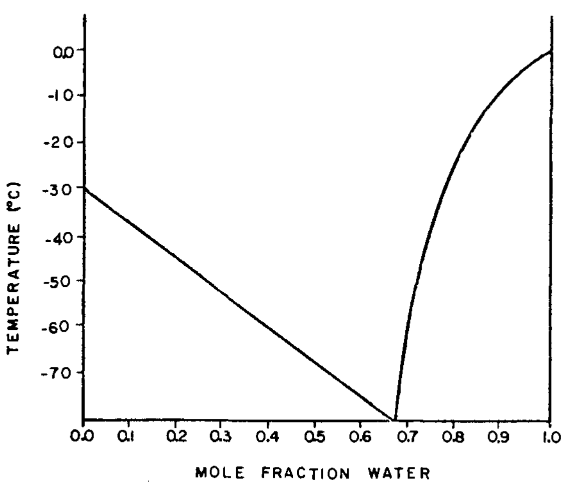
PHASE DIAGRAM FOR THE TERNARY SYSTEM

1-FORMYLPIPERIDINE, WATER, CYCLOHEXANE at 25°C, 1 ATMOSPHERE

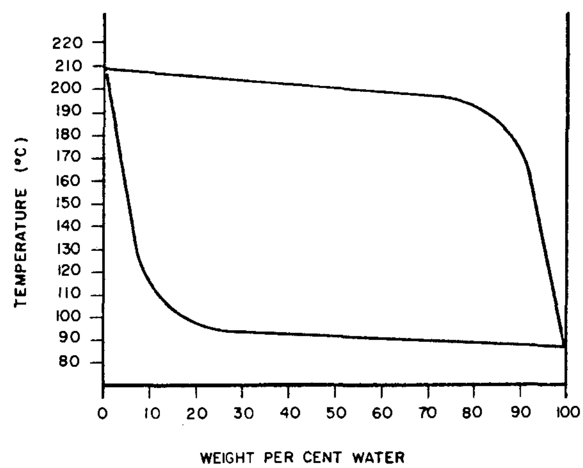


CLAUSIUS-CLAPEYRON PLOT

VAPOR PRESSURE 1-FORMYLPIPERIDINE



FREEZING POINT-COMPOSITION DIAGRAM FOR THE 1-FORMYLPIPERIDINE, WATER SYSTEM



LIQUID-VAPOR COMPOSITION DIAGRAM FOR THE 1-FORMYLPIPERIDINE, WATER SYSTEM

NITRILES

Table 14.106: n-Butyronitrile *(19)*

$$CH_3CH_2CH_2C{\equiv}N$$

n-Butyronitrile is a clear, colorless liquid which is slightly soluble in water and completely miscible with common organic solvents. The product undergoes reactions typical of the aliphatic nitriles.

Physical Properties

Molecular weight	69.10
Specific gravity, 20/20°C	0.7920
Boiling point, 760 mm	117.5°C
50 mm	43°C
10 mm	13°C
Vapor pressure, 20°C	15 mm
Freezing point	-111.90°C
Solubility, in water, 20°C	3.5% by wt.
water in, 20°C	2.5% by wt.
Viscosity, 0°C	0.8 cps.
20°C	0.6 cps.
40°C	0.5 cps.
Refractive index, n_D^{20}	1.3841
Weight per gallon, 20°C	6.60 lbs.
Flash point	79°F

Shipping Data

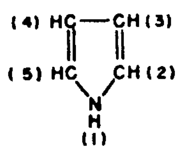
Net Container Contents:	
1-gallon tin can	6.5 lbs.
5-gallon iron drum	30 lbs.
55-gallon iron drum	360 lbs.

Typical Analysis of Current Production

Specific gravity	0.7907
Distillation, IBP	115.7°C
50 ml	117.6°C
DP	118.4°C
n-Butyronitrile	98.9% by wt.
Water	0.09% by wt.
Alkalinity	0.22 meq/gm
Color	5 Pt-Co

HETEROCYCLIC COMPOUNDS

Table 14.107: Pyrrole *(49)*

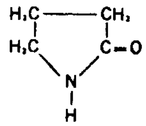


Appearance	Colorless liquid, darkens on standing
Odor	Mild, nonirritating
Molecular Weight	67.09
Boiling Point*	129°C. (264°F.) at 760 mm.
Freezing Point*	-24°C. (-11°F.)
Specific Gravity, 20/4°C.*	0.968
Index of Refraction, n20/D*	1.5095
Flash Point (Tag closed cup)	39°C. (102°F.)
Modified Reid Vapor Pressure*	0.25 p.s.i. (±0.05)

*Determined on purified pyrrole

Table 14.108: 2-Pyrrolidone *(49)*

CHEMICAL STRUCTURE **2-PYROL®:**



2-pyrrolidone

Molecular Weight 85

PHYSICAL PROPERTIES* **Physical Characteristics of 2-PYROL:**

Physical State	Liquid
Boiling Point at 760 mm	245°C
Boiling Point at 400 mm	226°C
Boiling Point at 200 mm	202°C
Boiling Point at 100 mm	181°C
Boiling Point at 60 mm	170°C
Boiling Point at 40 mm	155°C
Boiling Point at 20 mm	138°C
Boiling Point at 10 mm	122°C
Density at 25°C	1.107 g/ml
Density at 50°C	1.087 g/ml
Density at 75°C	1.067 g/ml
Density at 100°C	1.046 g/ml
Density at 125°C	1.025 g/ml
Density at 150°C	1.005 g/ml
Density at 175°C	0.985 g/ml
Viscosity at 25°C	12.0 cs or 13.3 cp
Refractive Index n_D^{25}	1.486
Flash Point (open cup)	129.4°C (265°F)
Fire Point	145°C (293°F)
pH (10% aqueous solution)	8-10

As shipped, 2-PYROL meets a specification of 98.5% minimum purity, 0.5% maximum moisture.

Solubility: 2-PYROL is completely soluble in

water	chloroform	ethyl acetate
ethyl alcohol	benzene	carbon disulfide
ethyl ether		

Dissolves polymers
chlordane
DDT
d-sorbitol
glycerine
iodine
sugars

*These data are typical of current production but are not specifications

Table 14.109: Phase Diagram for 2-Pyrrolidone-Water *(49)*

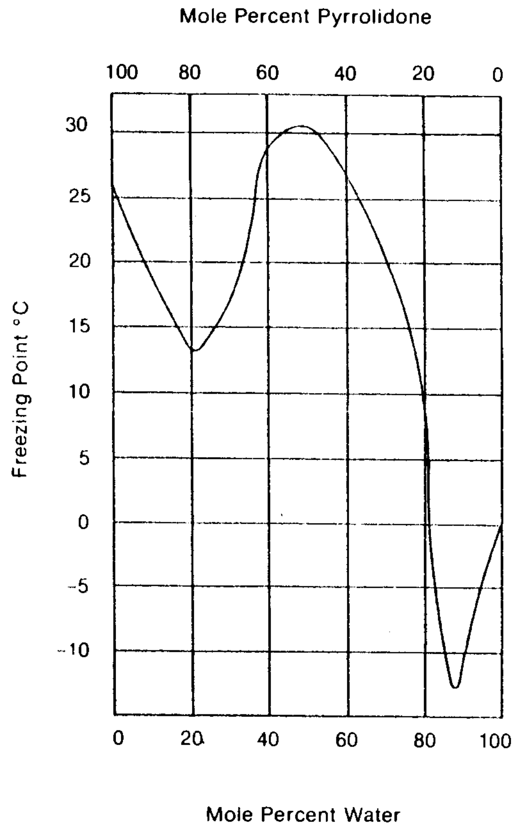
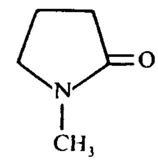


Table 14.110: N-Methyl-2-Pyrrolidone *(49)*

Structural Formula

M-PYROL



Empirical Formula C_5H_9NO

		CGS	ENGLISH
Molecular Weight		99.1	99.1
Purity (N-methyl-2-pyrrolidone, area% VPC)		99.8% min	
Physical form		liquid with mild amine-like odor	
Moisture Content		0.05% max	0.05% max
Density - Liquid	**(20°C)**	1.03 gm/cc	64.3 lb/ft^3
	(30°C)	1.02 gm/cc	63.8 lb/ft^3
	(40°C)	0.99 gm/cc	61.8 lb/ft^3
Boiling Point	**@ 760mm**	202°C	395°F
	@ 162mm	150°C	302°F
	@ 24mm	100°C	212°F
Freezing Point		-29.4°C	-11.9°F
Viscosity	**(20°C)**	1.7 cp	4.11 lb/ft-hr
	(50°C)	1.0 cp	2.41 lb/ft-hr
	(80°C)	0.9 cp	2.17 lb/ft-hr
Specific Gravity (d^{25}_4)		1.027	
	@ 75°C	0.987	
	@ 100°C	0.969	
Interfacial Surface Tension (25°C)		40.7 dynes/cm	
Flash Point (ASTM D 93-72)		93°C	199°F
Heat of Vaporization — 100°C		127.3 K cal/kg	230 BTU/lb
Specific Heat - Liquid	**(0°C)**	0.401 cal/g-°C	0.401 BTU/lb-°F
	(50°C)	0.465 cal/g-°C	0.465 BTU/lb-°F
	(100°C)	0.502 cal/g-°C	0.502 BTU/lb-°F
Specific Heat - Vapor (25°C)		0.301 cal/g-°C	0.301 BTU/lb-°F
Vapor Pressure -	**(40°C)**	1.0 Torr	0.02 psi
	(60°C)	3.5 Torr	0.07 psi
	(80°C)	9.5 Torr	0.19 psi
Refractive Index		1.4700	1.4700
Heat of Combustion		7.29 kcal/g	13,100 BTU/lb
Dipole Moment		4.09 ± 0.04 Debye	
Dielectric Constant (25°C)		32.2	
Ignition Temperance (ASTM D 286-58 T)		270°C	518°F
Flammable Limits in Air	**Upper**	9.5 vol %	9.5 vol. %
	Lower	1.3 vol. %	1.3 vol. %
Thermal Conductivity (25°C)		1.33 W/cm-°C	1.13 BTU-in/ft.^{2} hr°F
Hansen Solubility parameters:			
		δd 8.8 $(cal/cm^3)^{1/2}$	
		δp 6.0 $(cal/cm^3)^{1/2}$	
		δh 3.5 $(cal/cm^3)^{1/2}$	
		δt 11.2 $(cal/cm^3)^{1/2}$	
Kauri-Butanol Value (ASTM D1138-83)		>300	

Table 14.111: Acute Oral Toxicity *(49)*

M-Pyrol shows a low order of oral toxicity for each of the species investigated.

LD_{50}	Species	Reference
4.1 g/kg	Mouse	(1)
7.5 g/kg	Mouse	(2)
4.2 g/kg	Rat	(3)
3.8 ml/kg	Rat	(2)
3.5 ml/kg	Rat	(4)
4.4 g/kg	Guinea Pig	(5)
3.5 g/kg	Rabbit	(5)
2.5-5.0 g/kg	Bobwhite Quail	(6)

Table 14.112: Acute Dermal Toxicity *(49)*

M-Pyrol is readily absorbed through the skin and shows dermal toxicity of approximately the same magnitude as oral toxicity.

LD_{50}	Species	Reference
7.0 g/kg	Rat	(1)
5-10 g/kg	Rat	(8)
4-8 g/kg	Rabbit	(6)
2-4 g/kg	Rabbit (abraded skin)	(6)

Table 14.113: Injection Toxicity *(49)*

As might be expected, M-Pyrol is slightly more toxic by injection than by the other modes of application. Differences, however, are generally small so that toxicity is still low.

Injection mode	LD_{50}	Species	Reference
Intraperitoneal	4.3 ml/kg	Mouse	(2)
Intraperitoneal	1.9 ml/kg	Mouse	(4)
Intraperitoneal	2.4 ml/kg	Rat	(2)
Intravenous	3.5 ml/kg	Mouse	(2)
Intravenous	2.4 ml/kg	Rat	(2)

Intravenous injection of M-Pyrol in rats was studied, monitoring arterial blood pressure, blood glucose levels and electrocardiograms. Doses of 50 mg/kg produced a slight and short-lived hypotension without altering the ECG; hyperglycemia was observed at the higher dosage only. At 500 mg/kg, hypotension, hyperglycemia, and ECG alterations were all produced.

Table 14.114: Toxicity to Aqueous Organisms *(49)*

M-Pyrol shows low toxicity for all of the aquatic animals tested.

LC_{50}	Species	Reference
0.8 ml/l	Sunfish	(6)
1.1 ml/l	Fathead Minnow	(6)
3.0 ml/l	Trout	(6)
1.3 ml/l	Guppy	(1)
4.9 ml/l	Daphnia	(6)
4.7 ml/l	Scud	(6)
1.6 ml/l	Mud Crab	(6)
1.1 ml/l	Grass Shrimp	(6)

Table 14.115: Infrared Absorption Spectrum *(49)*

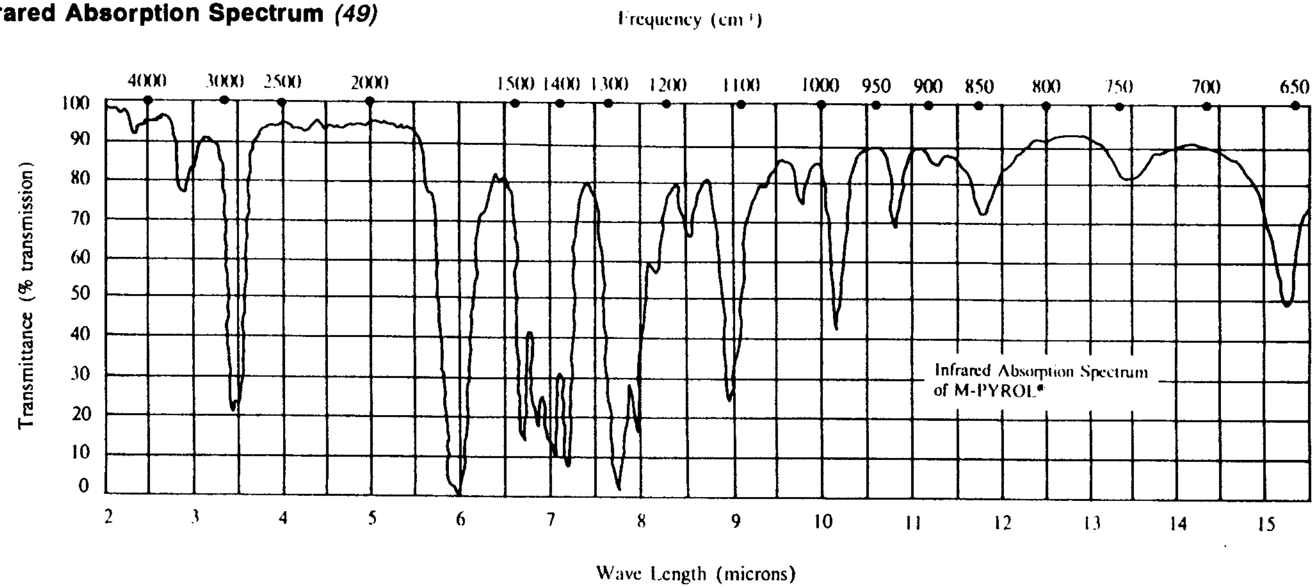


Table 14.116: Specific Heat *(49)*

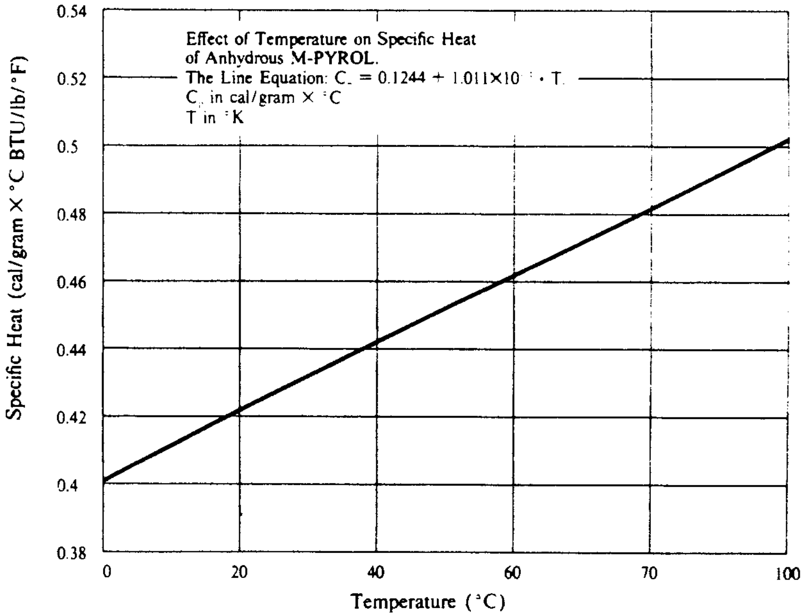


Table 14.117: Thermal Conductivity *(49)*

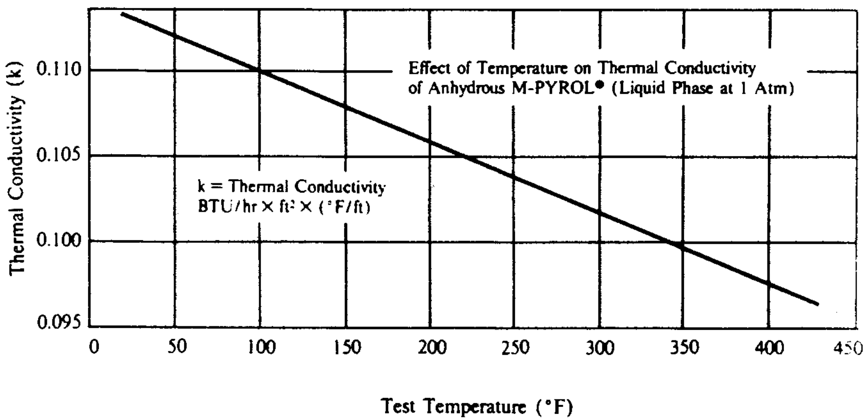


Table 14.118: Vapor Pressure *(49)*

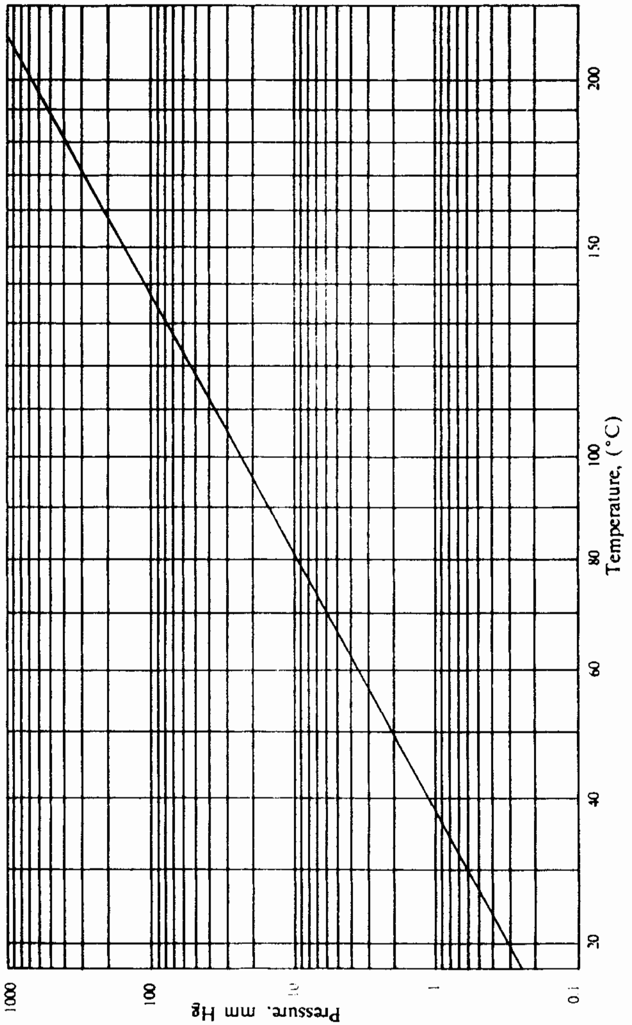


Table 14.119: Comparison of Vapor Pressures of M-Pyrol and Other Aprotic Solvents *(49)*

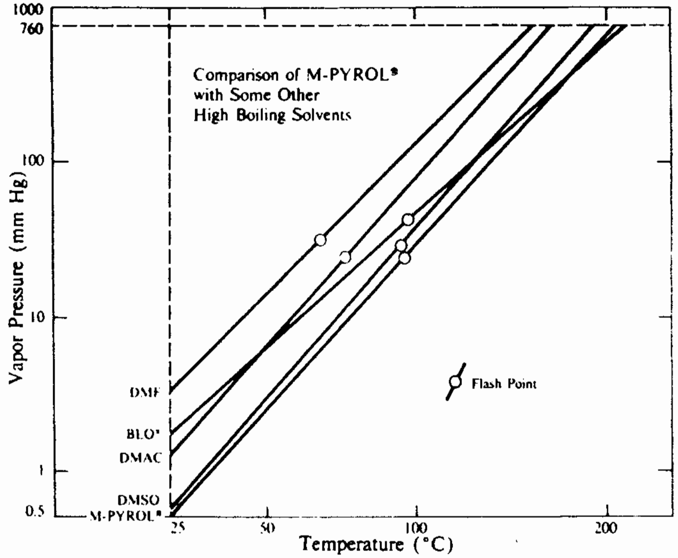
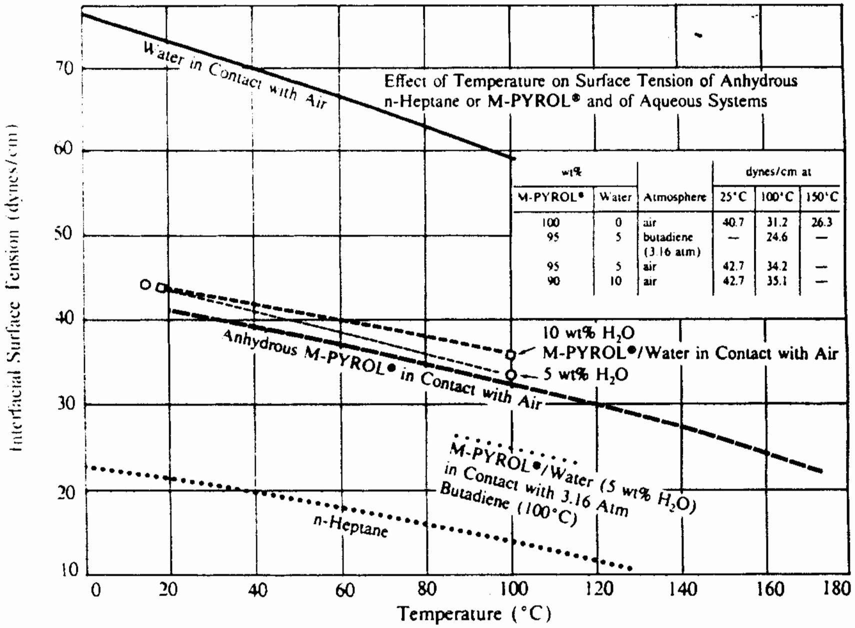
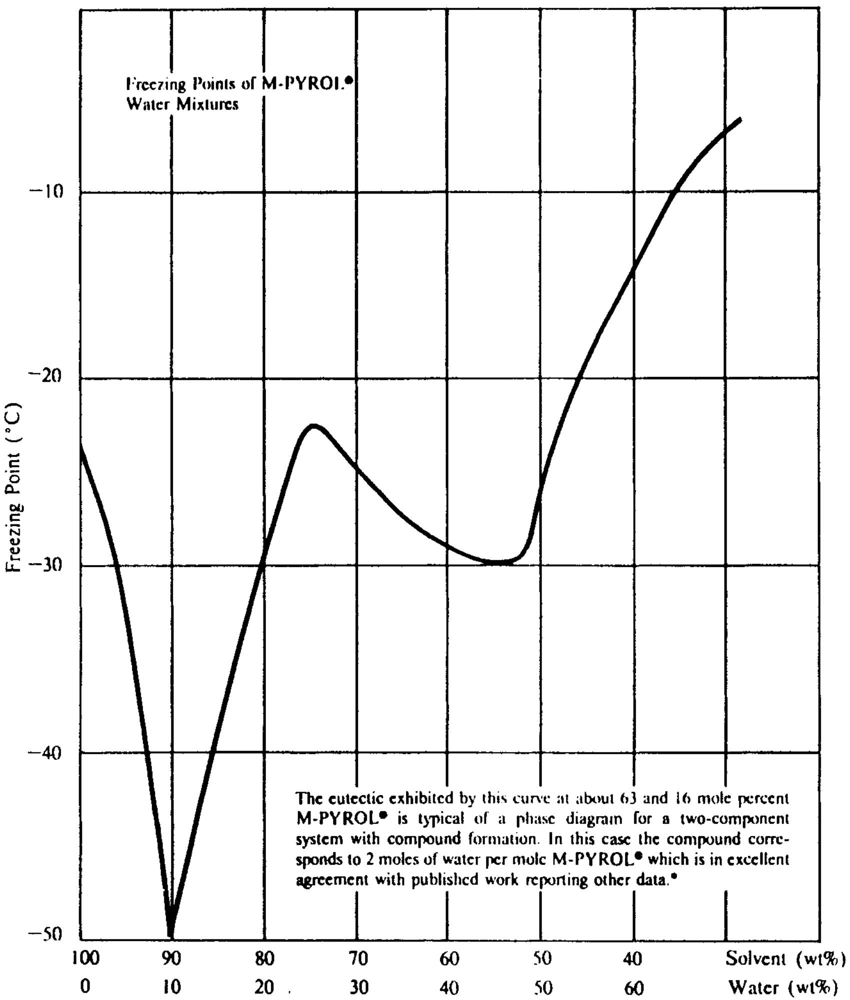


Table 14.120: Surface Tension *(49)*



wt%			dynes/cm at		
M-PYROL®	Water	Atmosphere	25°C	100°C	150°C
100	0	air	40.7	31.2	26.3
95	5	butadiene (3.16 atm)	—	24.6	—
95	5	air	42.7	34.2	—
90	10	air	42.7	35.1	—

Table 14.121: Freezing Point Curve *(49)*



* Virtanen, P.O.I. and Korpela, J. *Suomen Kemistrilehti* B40:99-103 (1967); Virtanen, P.O.I. *ibid* B-40:241-9 (1967); *ibid* B40:313-16 (1967)

Table 14.122: Viscosity of Anhydrous M-Pyrol *(49)*

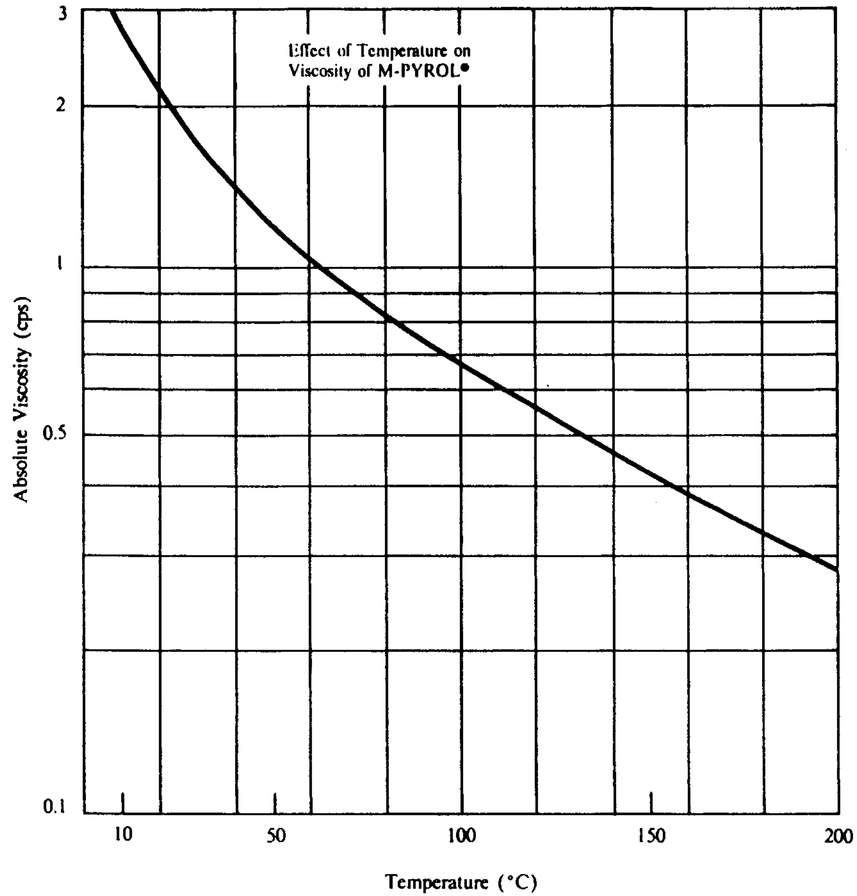


Table 14.123: Viscosity of Aqueous M-Pyrol *(49)*

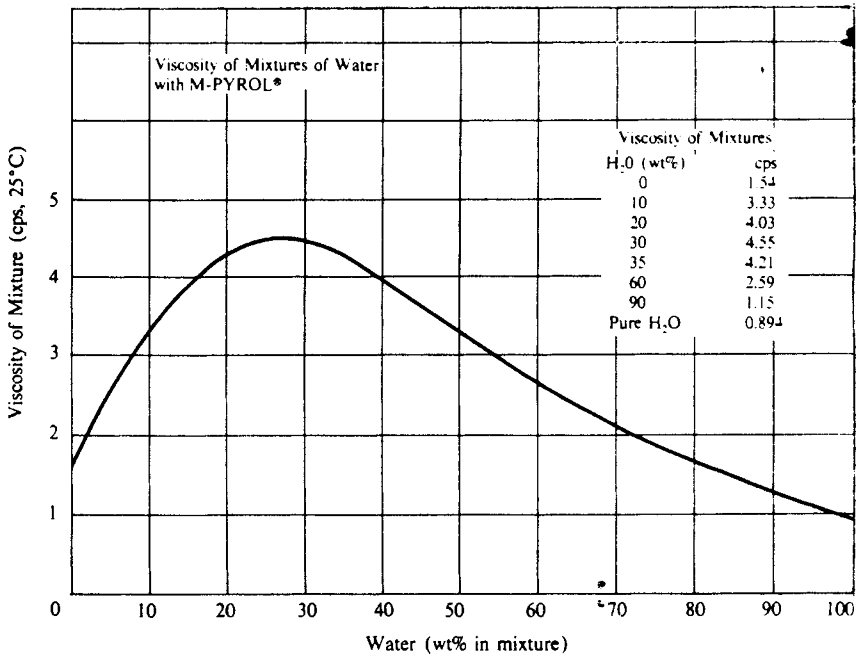
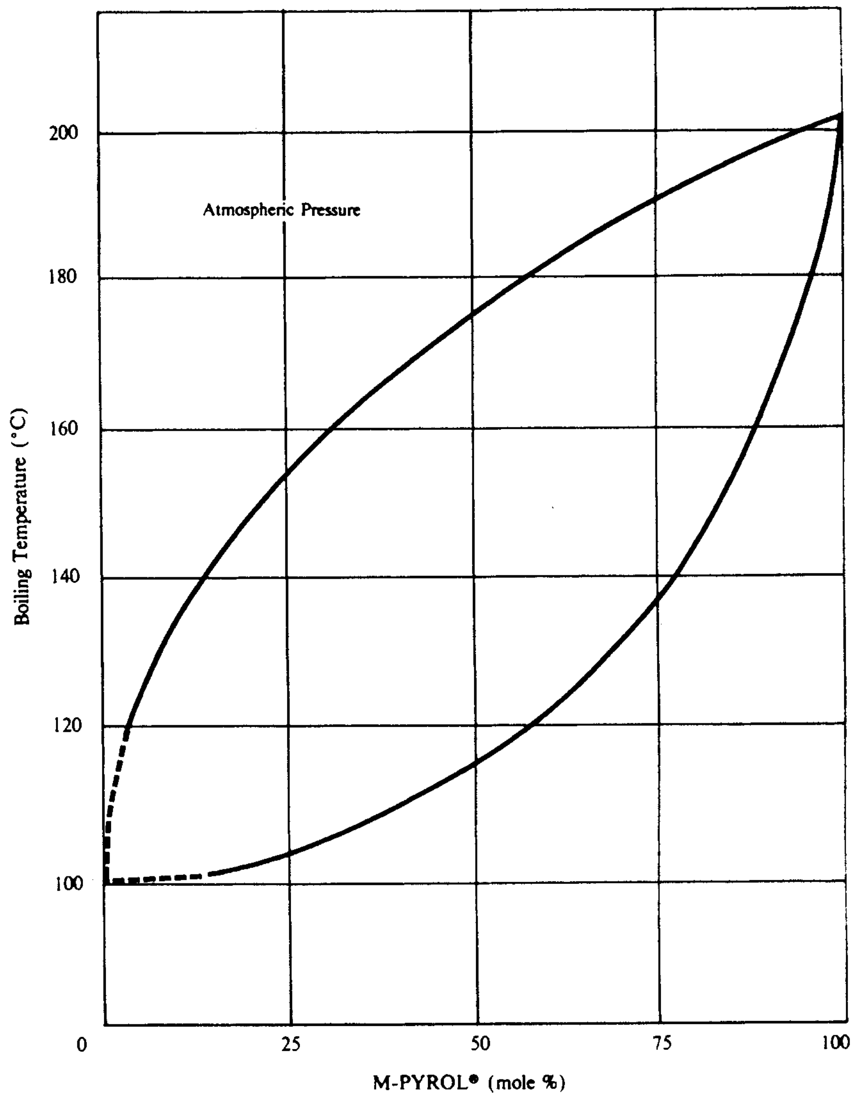
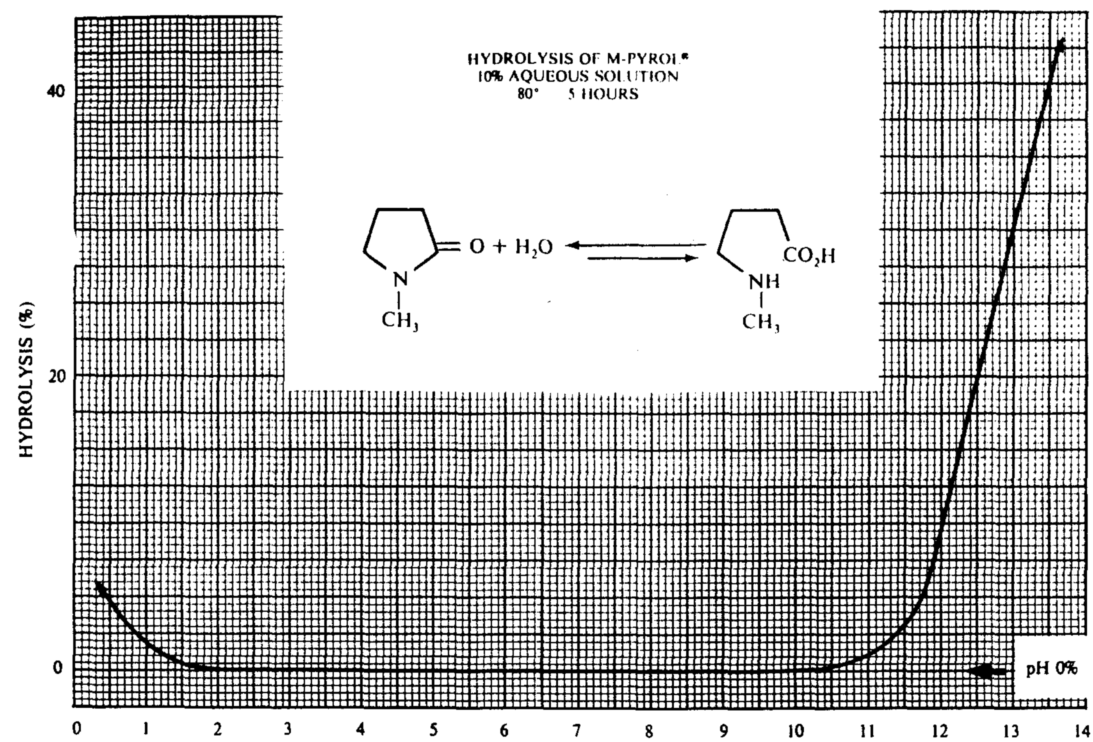


Table 14.124: Vapor/Liquid Equilibrium Data for M-Pyrol-Water System at Atmospheric and 400 mg Pressures *(49)*

Boiling Pt. °C	Pressure, mm	Mole-% M-PYROL® Liquid	Mole-% M-PYROL® Vapor	Weight-% M-PYROL® Liquid	Weight-% M-PYROL® Vapor
202	757.2	99.6	95.7	99.9	99.2
190	761.8	95.9	70.8	99.2	93.0
186	758.2	96.7	68.6	99.4	9.23
135	757.2	72.4	10.0	93.5	37.9
108	755.5	34.7	1.9	74.5	9.5
102	756.0	17.4	1.0	53.7	5.3
168	400.0	97.6	77.1	99.6	94.9
165	399.0	97.3	68.1	99.5	92.1
162	400.4	96.6	63.8	99.4	90.6

Table 14.125: Vapor/Liquid Equilibrium of M-Pyrol-Water Systems *(49)*





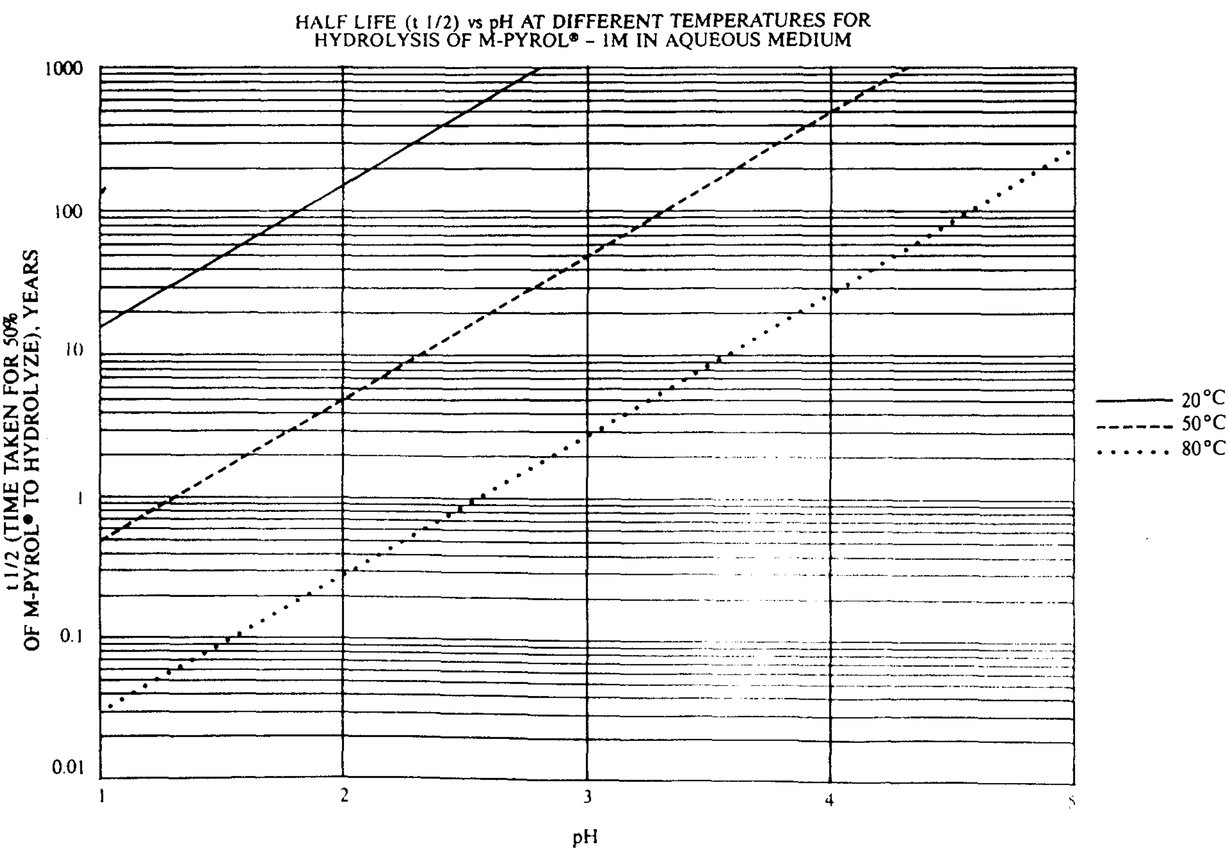


Table 14.126: Hydrolytic Stability of M-Pyrol *(49)*

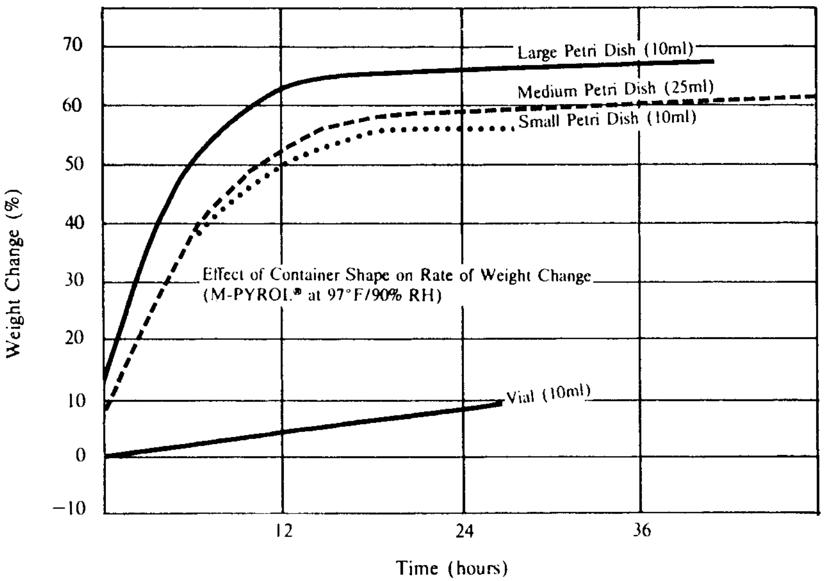
Table 14.127: Comparison of Hydrolysis of M-Pyrol and DMF *(49)*

Reagent	Time, Hours	Temp., °C	Conc., M-PYROL®	mol/1 DMF	Hydrolysis, %
0.5N NaOH	24	R.T.	0.40	0	0
0.5N NaOH	24	R.T.	0	0.39	90.4
0.5N H_2SO_4	24	R.T.	0.45	0	0
0.5N H_2SO_4	24	R.T.	0	0.42	0
0.25N NaOH	1	80	0.21	0	5.4
0.25N NaOH	1	80	0	0.22	100

Table 14.128: Hydrolysis of M-Pyrol in Alkaline Salt Solutions *(49)*

Alkaline Salt	pH 1% Solution	% Hydrolysis
Sodium tripolyphosphate	9.7	0.3
Potassium pyrophosphate	10.1	0.5
Sodium carbonate	11.4	1.5
Trisodium phosphate	12.0	4.7
Sodium metasilicate	12.6	18.3
Sodium hydroxide	13.2	39.7

Table 14.129: Hygroscopicity Data *(49)*



Note: Dynamic tests conducted in humidity cabinet having complete change of atmosphere every 3 minutes. Surface area to weight ratios of large Petri dish, small Petri dish, and vial were 17.0, 2.4, and 0.25, respectively.

Table 14.130: Hygroscopicity Data *(49)*

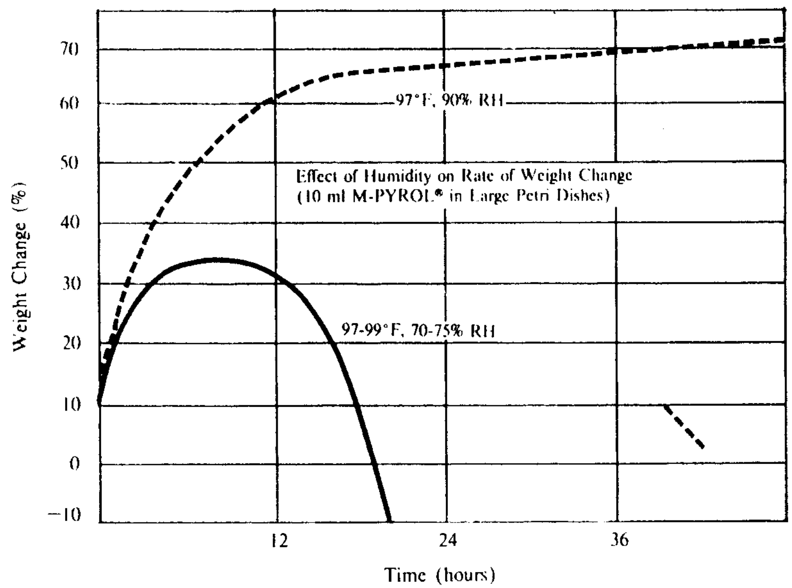


Table 14.131: Hygroscopicity Data *(49)*

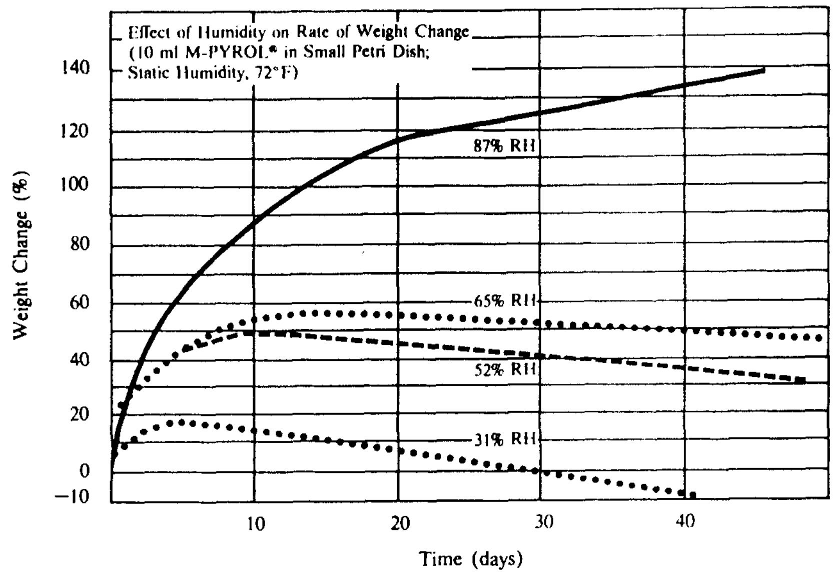


Table 14.132: Effect of Temperature on Hygroscopicity *(49)*

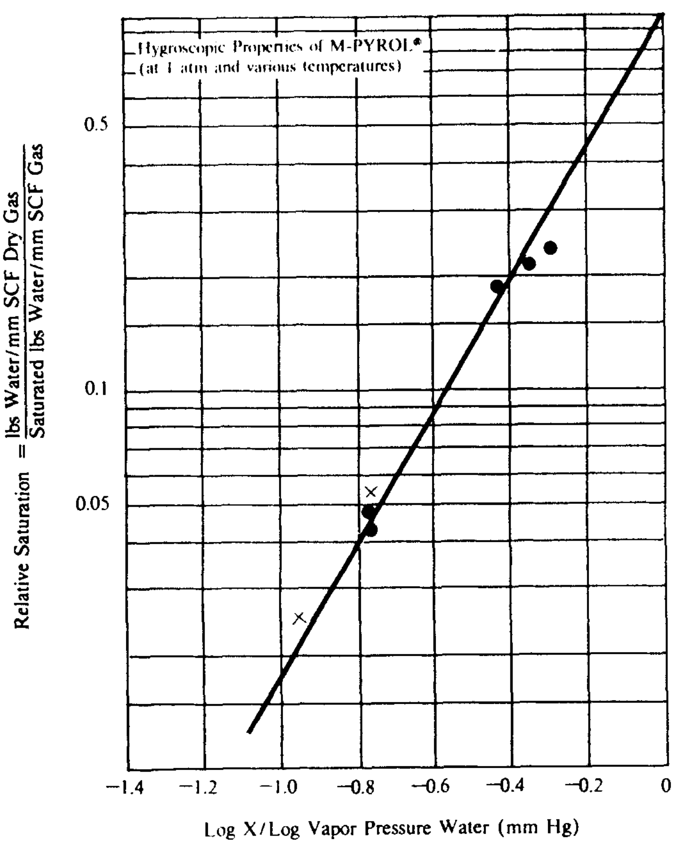


Table 14.133: Correlation of M-Pyrol and Water Vapor Data *(49)*

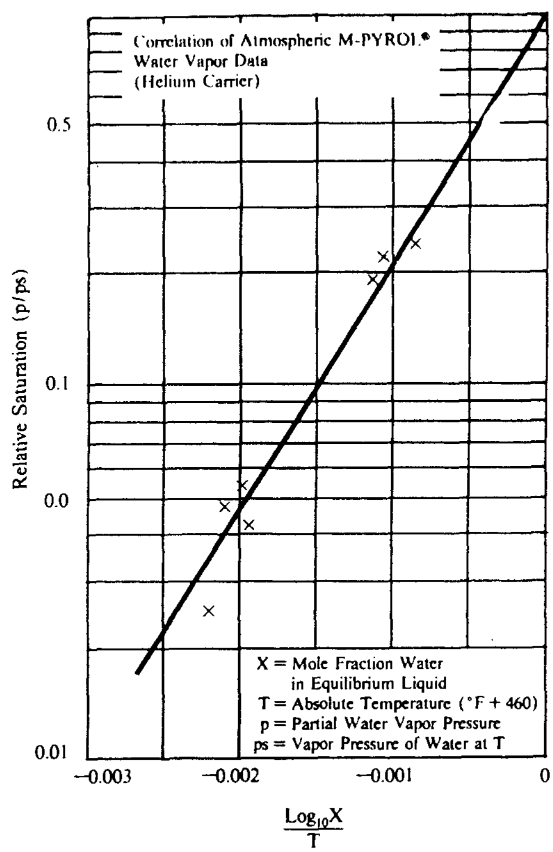
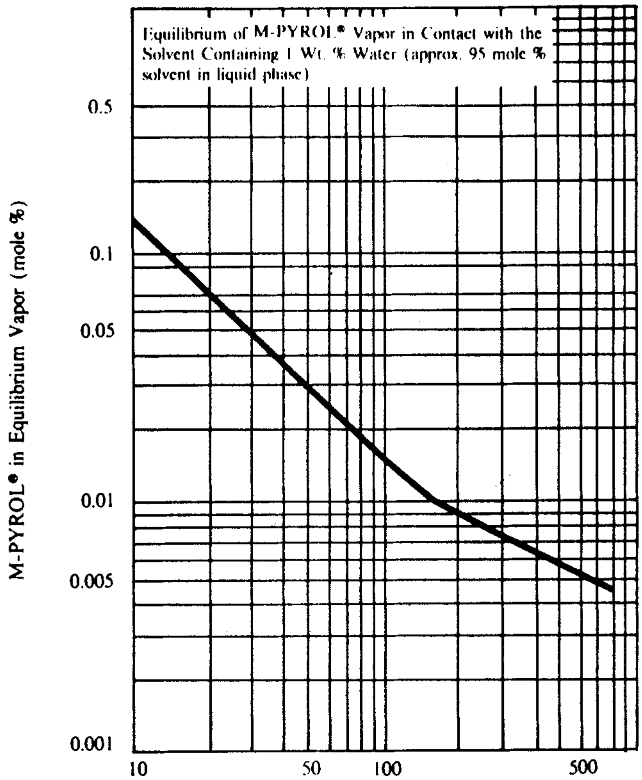


Table 14.134: Vapor/Liquid Equilibrium of M-Pyrol Containing 1% Water *(49)*



Natural Gas Composition (mole %)		Temperature (F)	psia	Vapor Composition (mole % Solvent)
N_2	4.35	100	765	0.0050
CH_4	90.04	100	797	0.0046
C_2H_6	3.30	100	560	0.0045
CO_2	1.84	100	435	0.0048
C_3	0.47	100	417	0.0058
		100	190	0.0086
		100	50	0.0168
		100	14.7	0.095*

*Calculated from 0.76 mm Hg vapor pressure.

Table 14.135: Solubility of Acetylene in Various Solvents *(49)*

Solvent	K Value (20 °C, 1 atm) ml gas / ml solvent	Solvent B. P., °C
M-PYROL®	43	202
Dimethylformamide	36	153
Dioxane	19.5	101
Acetone	17.5	56.5
BLO	17	204
Cyclohexanone	14	155

Table 14.136: Solubility of Sulfur Compounds and Carbon Dioxide in M-Pyrol Solvent *(49)*

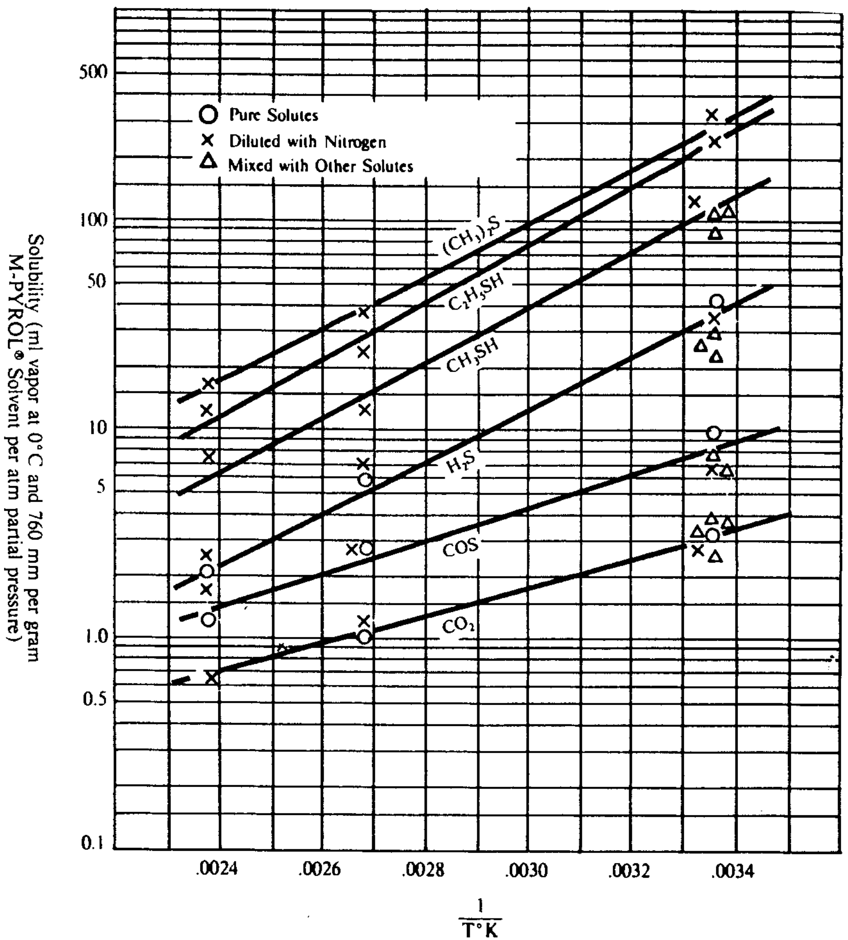


Table 14.137: Solubility of Paraffin Hydrocarbons in M-Pyrol Solvent *(49)*

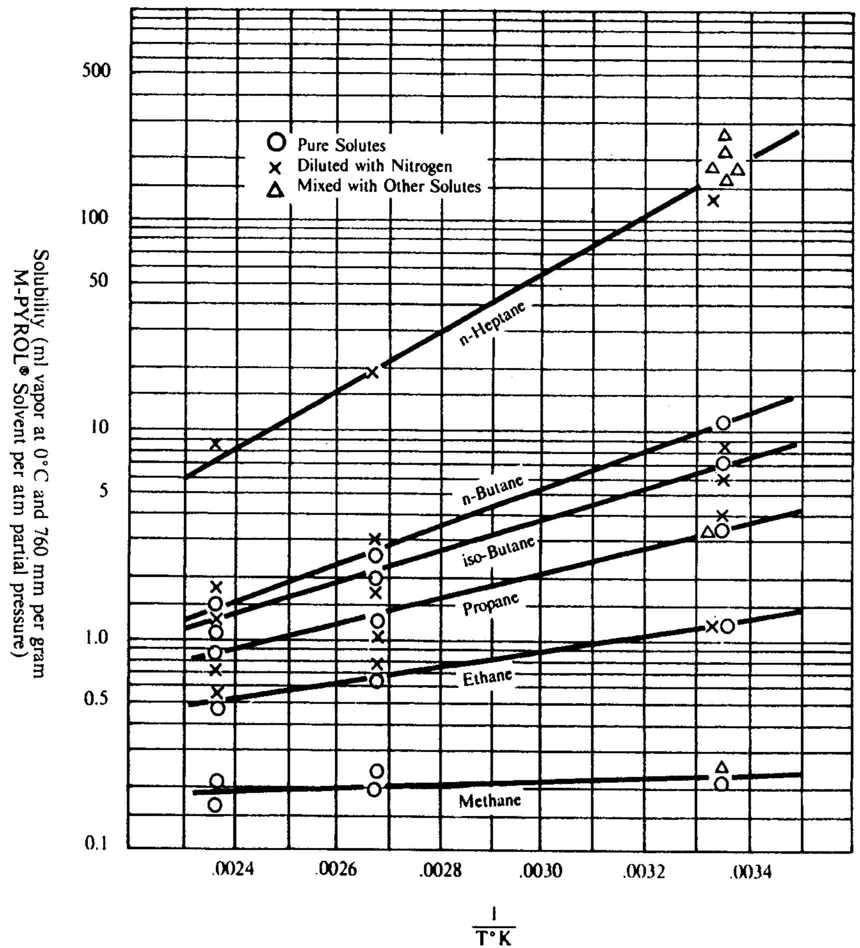


Table 14.138: Vapor-Liquid Equilibrium Distribution Coefficients for Sulfur Compounds and Carbon Dioxide in M-Pyrol Solvent *(49)*

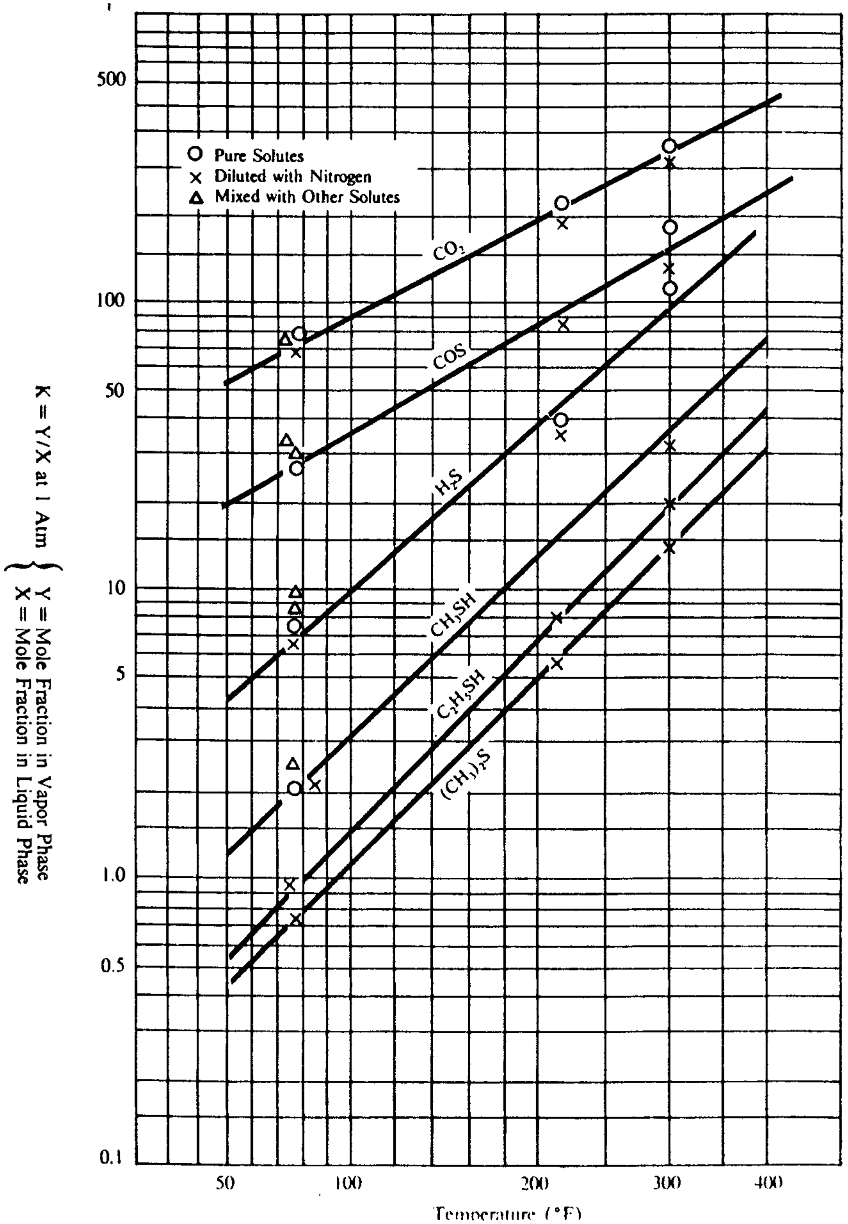


Table 14.139: Vapor-Liquid Equilibrium Distribution Coefficients for Paraffin Hydrocarbons in M-Pyrol Solvent *(49)*

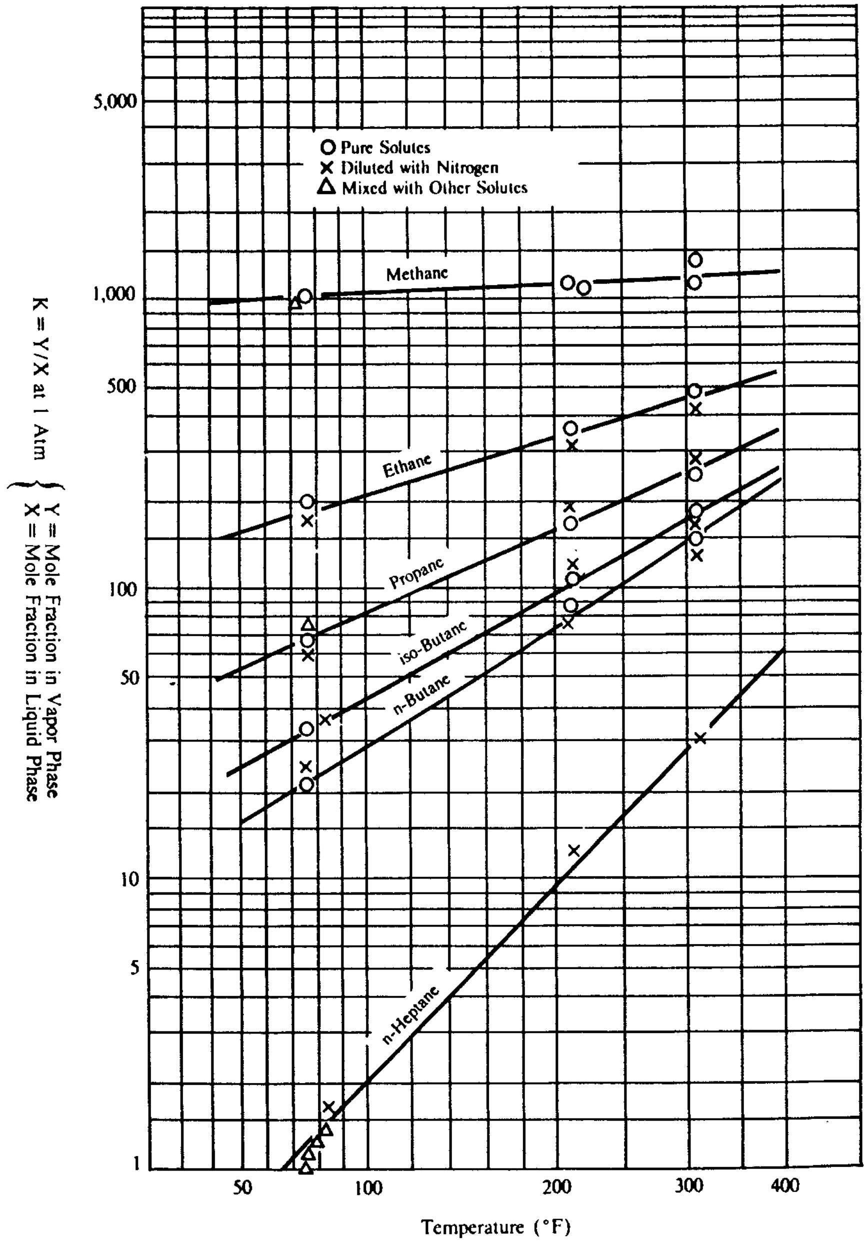


Table 14.141: Classification of Equilibria in M-Pyrol Showing Relationship Between Equilibrium Distribution Coefficients (K) and Solute Vapor Pressures *(49)*

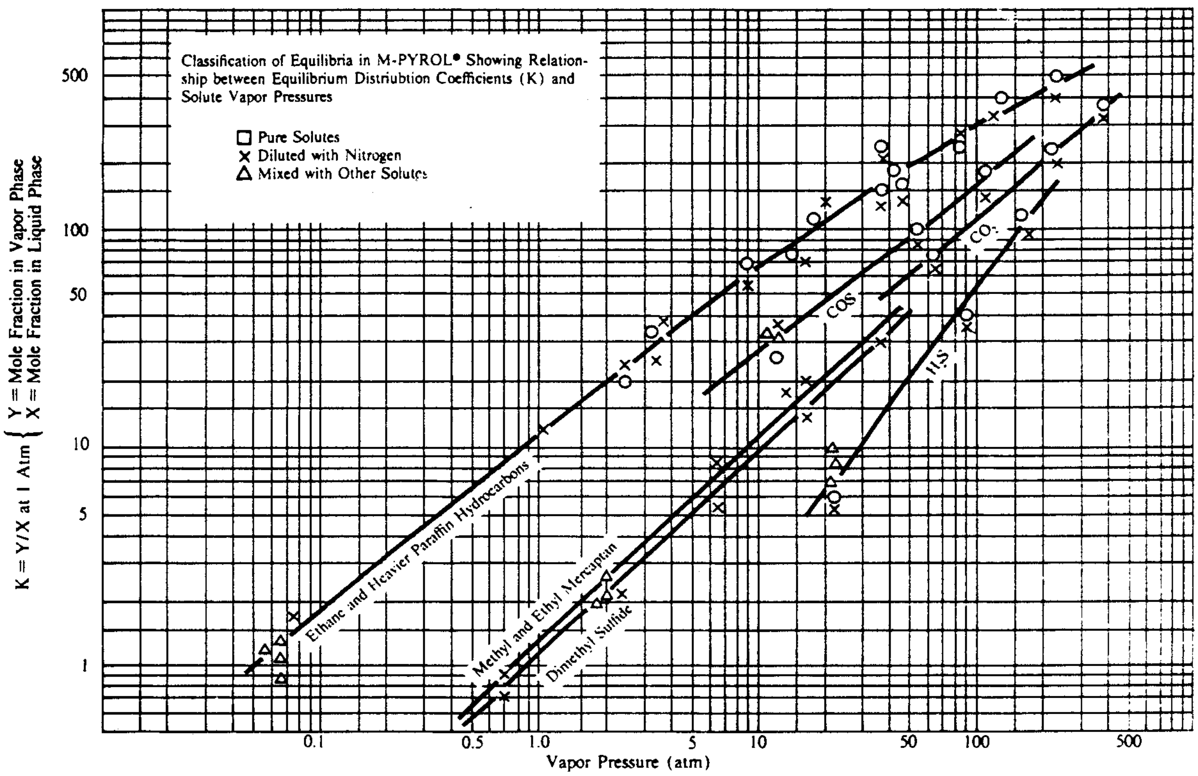


Table 14.140: Correlation of Equilibrium Distribution Coefficients for Ethane and Heavier Paraffin Hydrocarbons in M-Pyrol Solvent *(49)*

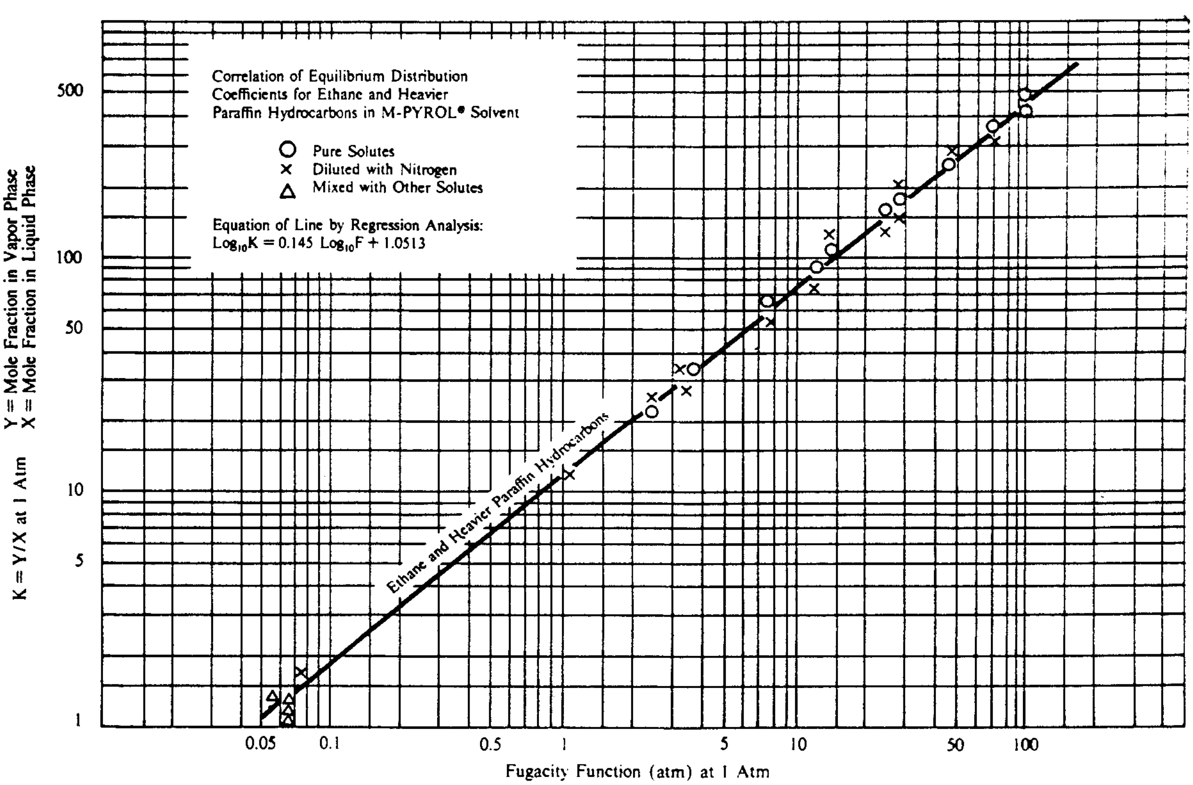


Table 14.142: Solubilities of Carbon Monoxide and Olefins in Anhydrous M-Pyrol Solvent *(49)*

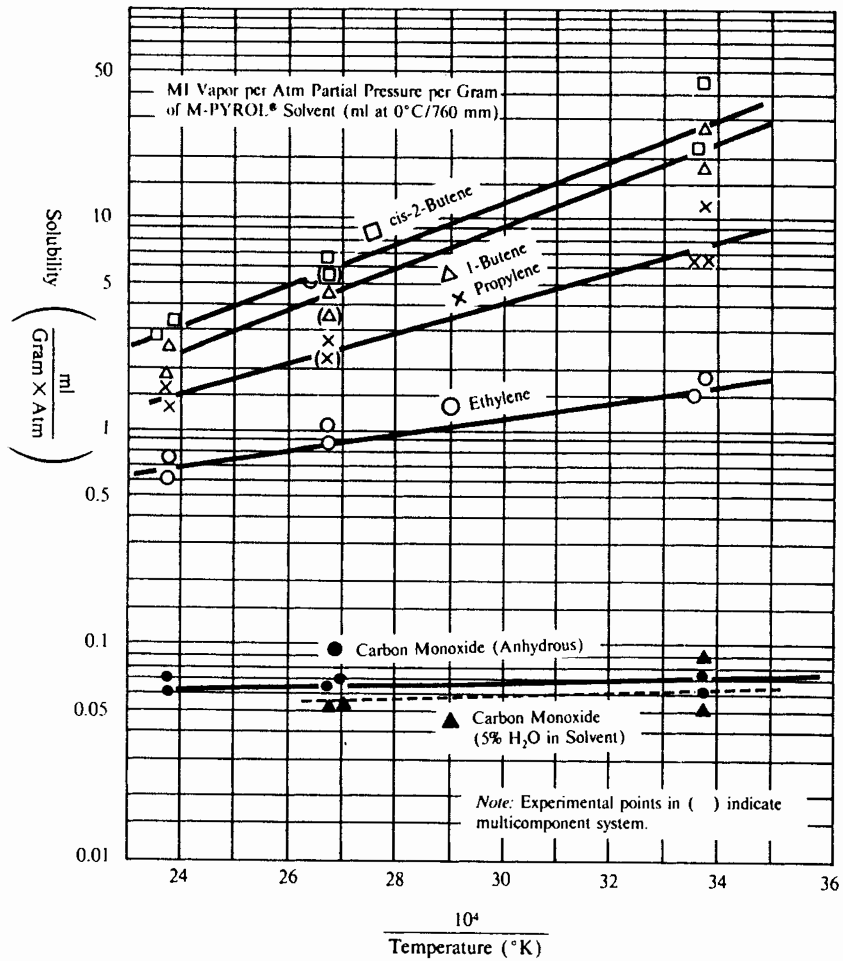


Table 14.143: Solubilities of Diolefins in Anhydrous M-Pyrol Solvent *(49)*

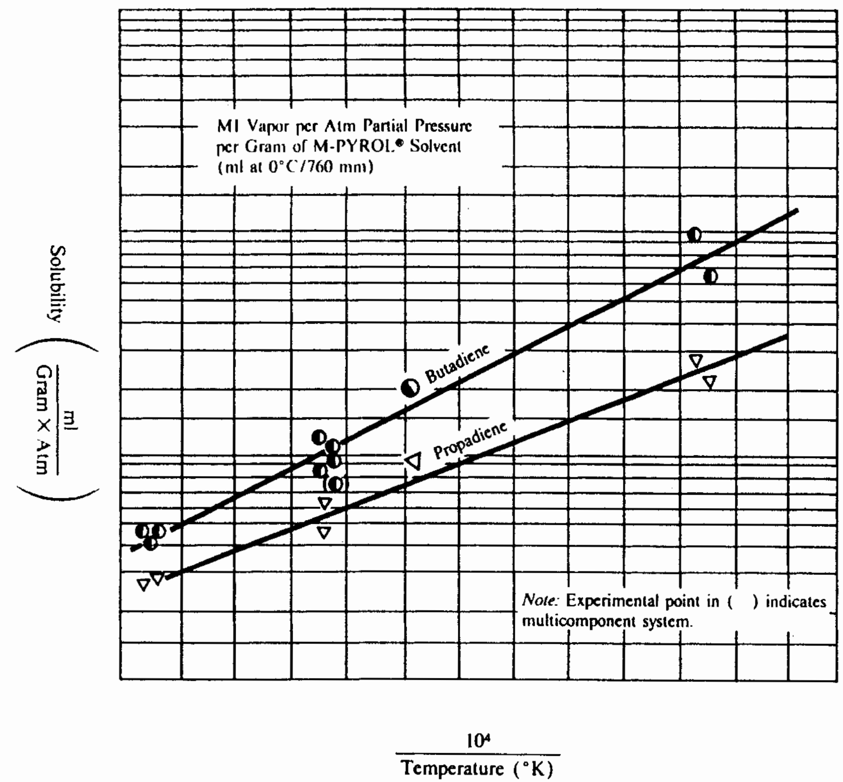


Table 14.144: Solubilities of Acetylenes in Anhydrous M-Pyrol Solvent *(49)*

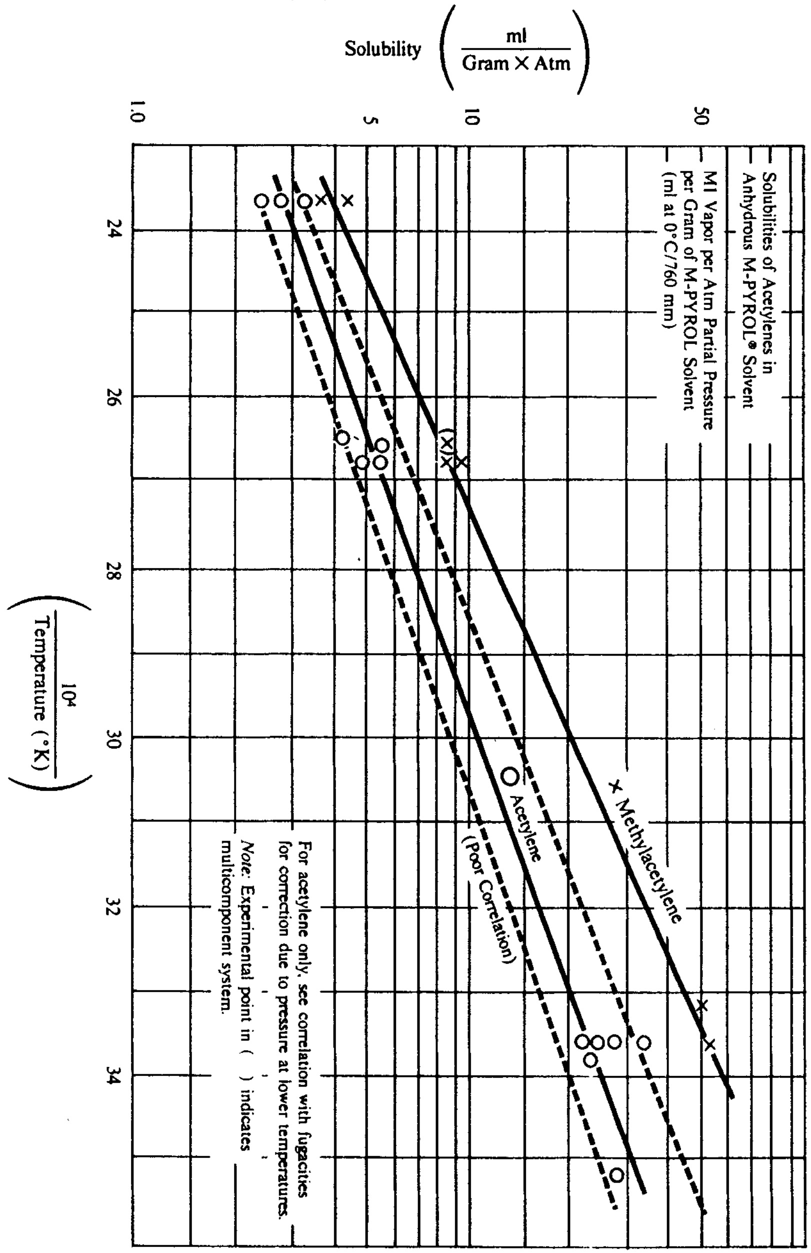


Table 14.145: Vapor-Liquid Equilibrium Distribution Coefficients for Olefins and Carbon Monoxide in M-Pyrol Solvent *(49)*

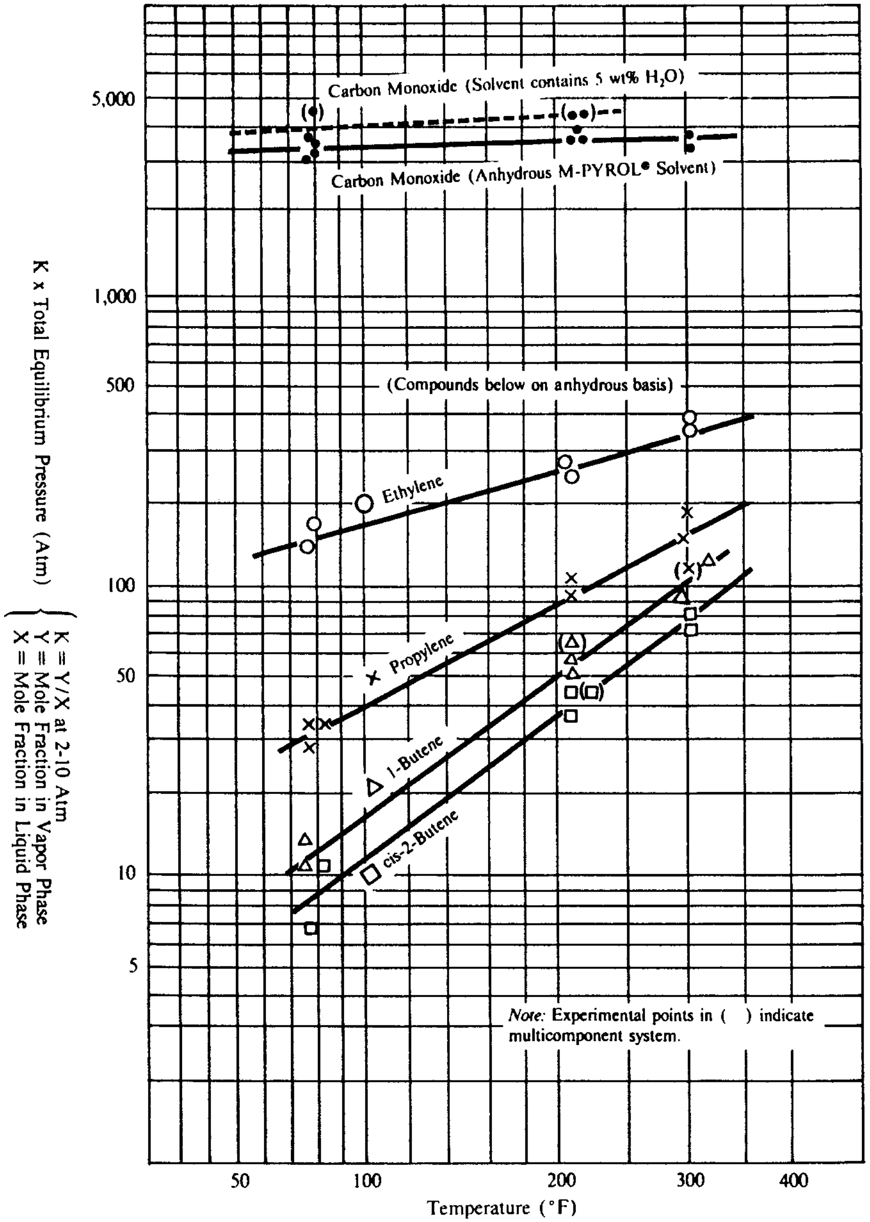


Table 14.146: Vapor-Liquid Equilibrium Distribution Coefficients for Diolefins in Anhydrous M-Pyrol Solvent *(49)*

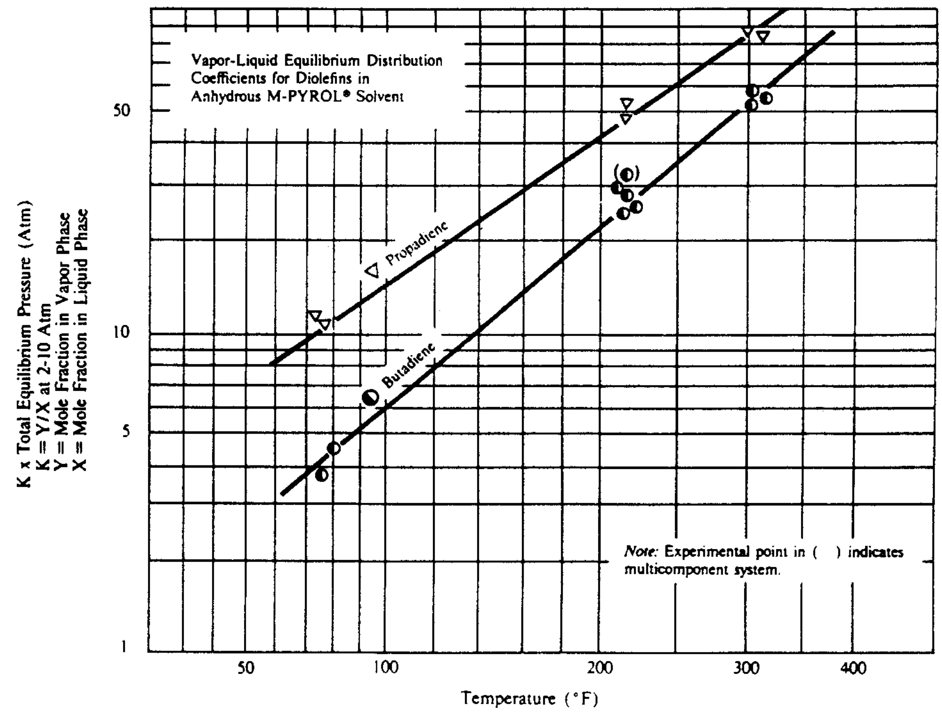


Table 14.147: Vapor-Liquid Equilibrium Distribution Coefficients for Acetylenes in Anhydrous M-Pyrol Solvent *(49)*

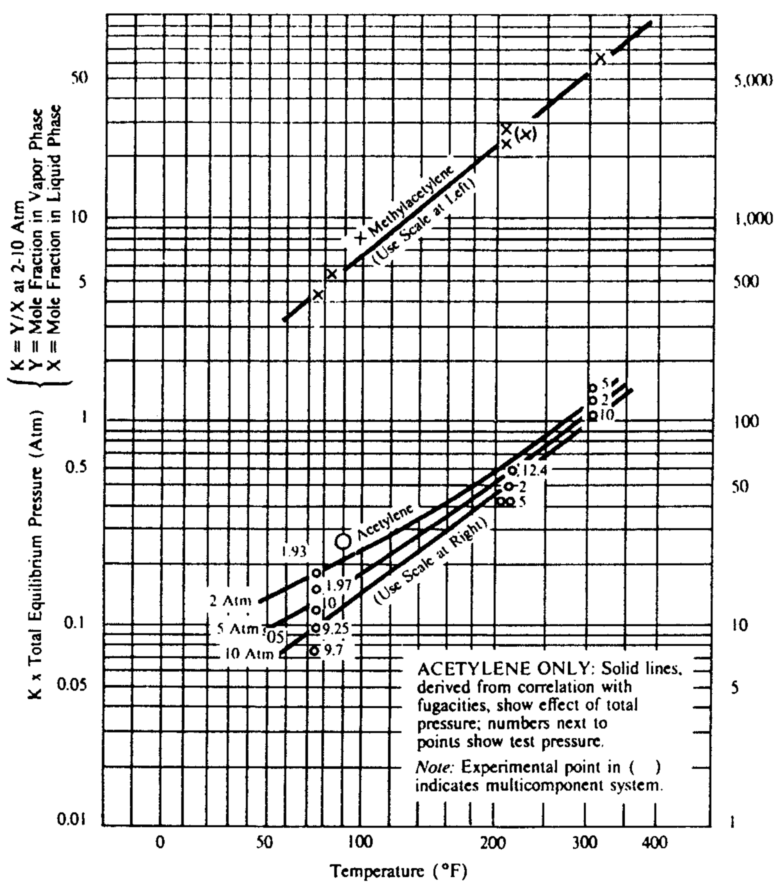


Table 14.148: Effect of Water (5 wt %) in M-Pyrol Solvent on Equilibrium Distribution Coefficients for Olefins *(49)*

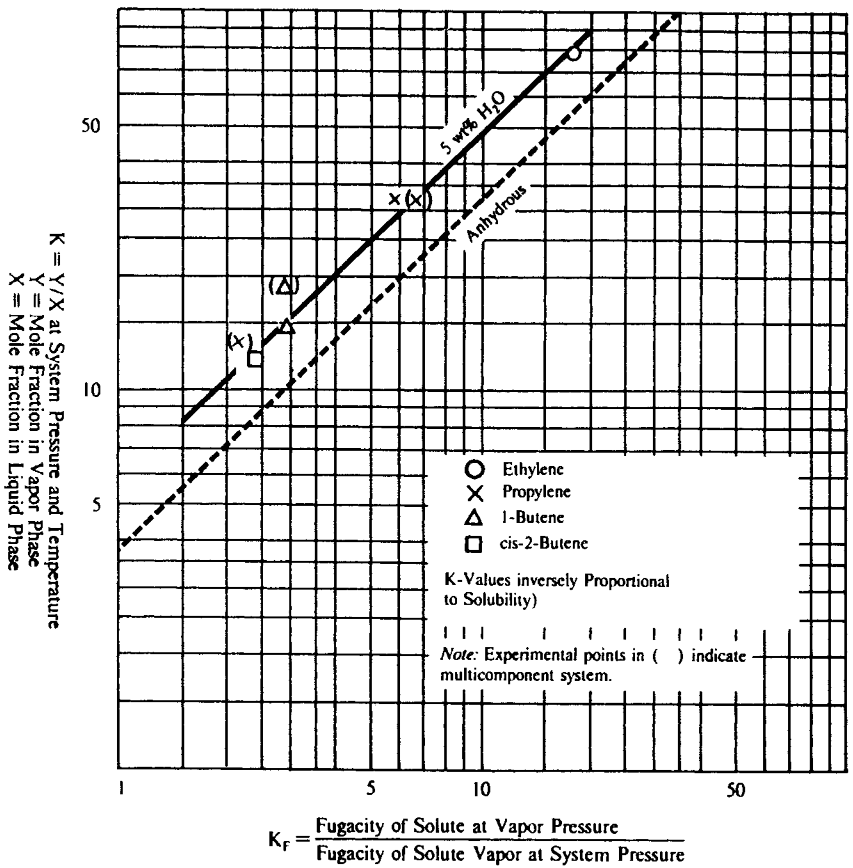


Table 14.149: Effect of Water (5 wt %) in M-Pyrol Solvent on Equilibrium Distribution Coefficients for Diolefins *(49)*

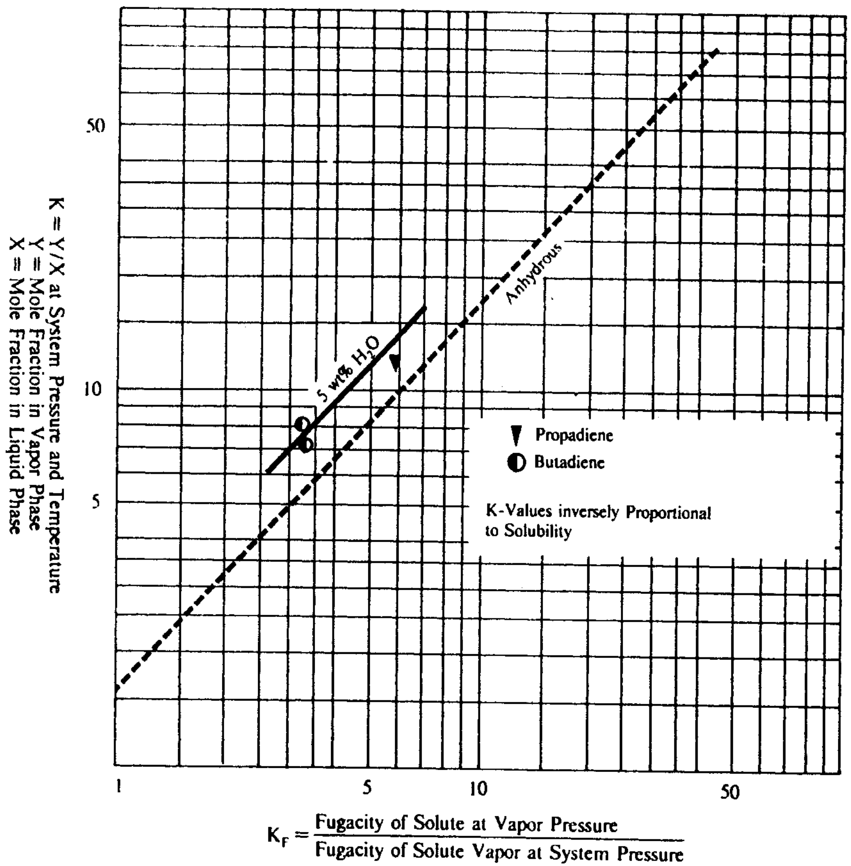


Table 14.150: Effect of Water (5 wt %) in M-Pyrol Solvent on Equilibrium Distribution Coefficient for Methylacetylene *(49)*

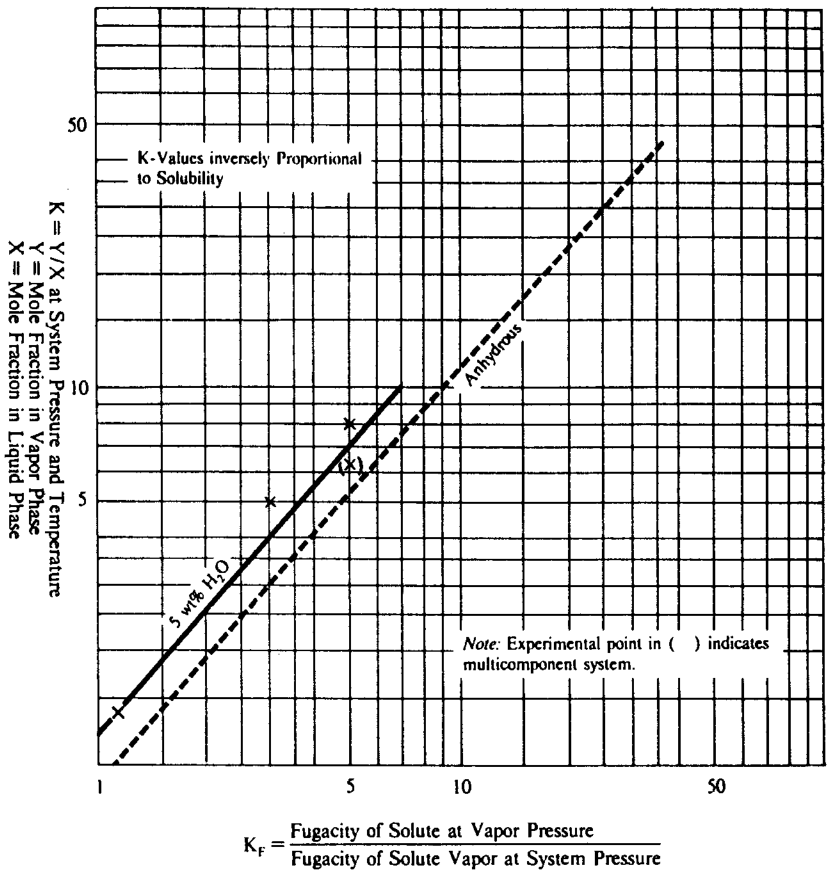


Table 14.151: Effect of Water (5 wt %) in M-Pyrol Solvent on Equilibrium Distribution Coefficient for Acetylene *(49)*

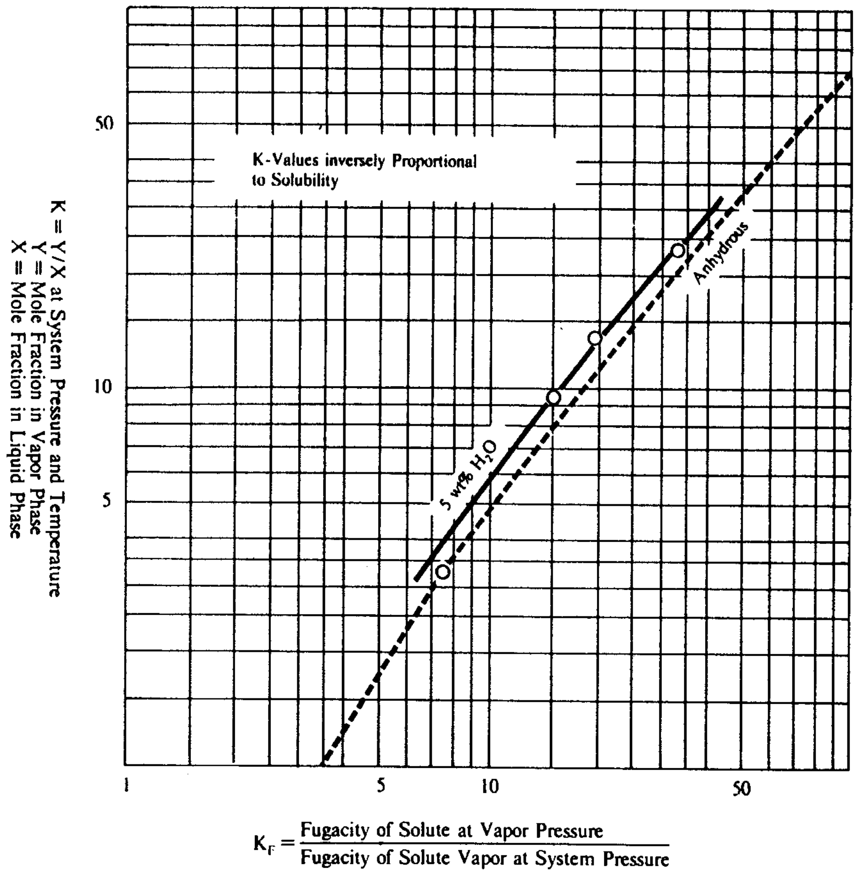


Table 14.152: Classification and Correlation of Equilibria of Unsaturated Hydrocarbons in Anhydrous M-Pyrol Solvent (2–10 atm, 25°–150°C range) *(49)*

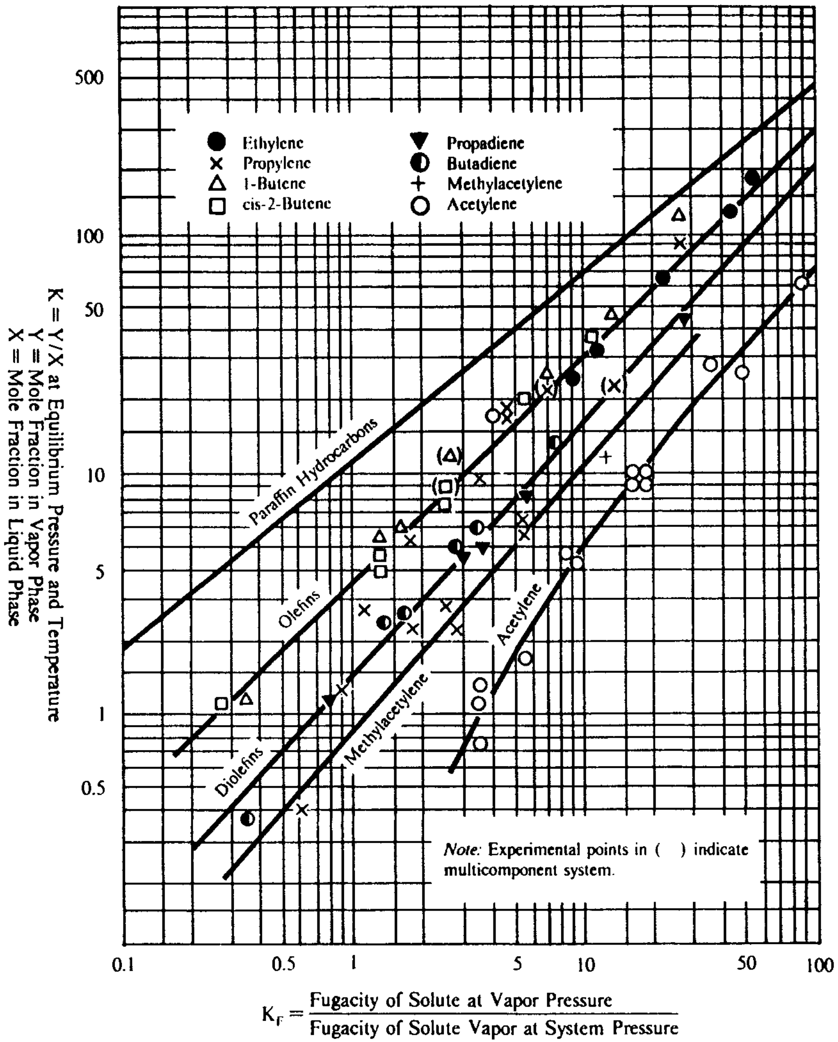


Table 14.153: Effect of Water and Elevated Pressure on Solubility of Hydrogen Sulfide in M-Pyrol Solvent *(49)*

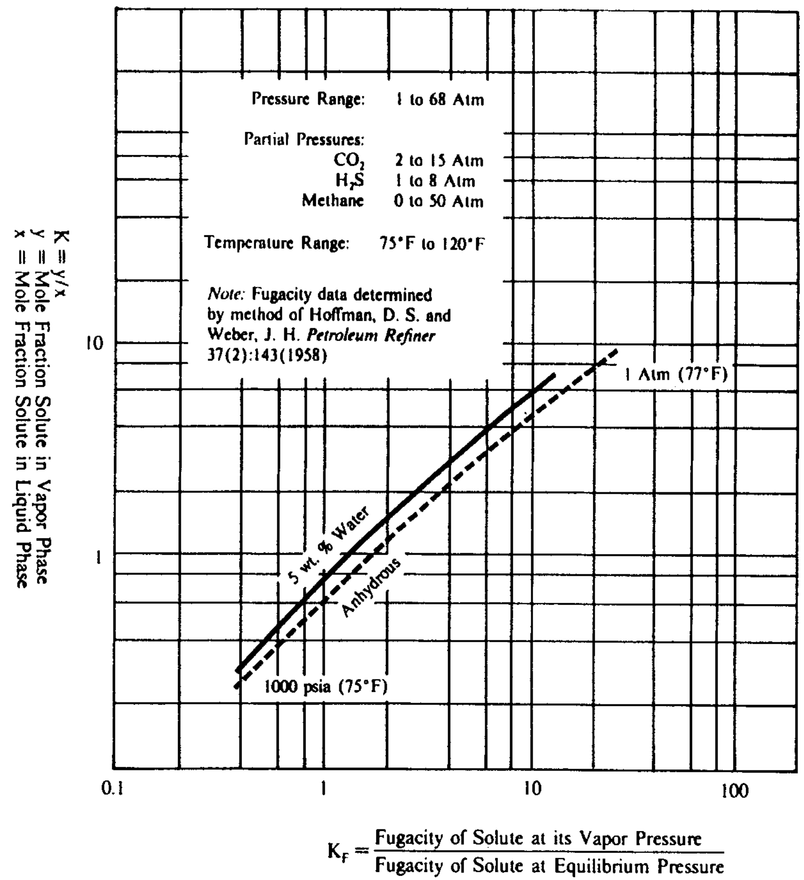


Table 14.154: Solubility of Polymers in M-Pyrol *(49)*

Polymer		Solubility, %*
Acrylonitrile/vinyl chloride copolymer		>10
Adiprene B urethane rubber (duPont)		10[a]
Black *Tervan* wax (Exxon)		>10
Cellulose triacetate		>10
Chemigum butadiene/acrylonitrile copolymer (Goodyear)		sol
Delrin polyacetal resin (duPont)		insol
Epi Rez 510 epoxy resin (Interchemical)		sol
Epolene N polyethylene (Eastman)		insol
Epon 1000, 1004, 1007 epoxy resin (Shell)		sol
Estane 5740X1 and 5740X2 polyurethane (Goodrich)		>10
Ethyl Cellulose N-100 (Hercules)		25
Formvar polyvinyl formal resin (Monsanto)		5
Gantrez AN methylvinylether/maleic anhydride copol. (GAF)		>10
Geon 101 and 102 polyvinyl chloride (Goodrich)		10
Hycar OR butadiene/acrylonitrile copolymer (Goodrich)		sol
Kynar polyvinylidene fluoride (Pennwalt)		sol
Lexan polycarbonate (General Electric)		10[b]
Mekon 20 wax (Petrolite)		>10
Multrathane MA-40 and MB-40 polyurethane (Mobay)		insol
Mylar polyester flim (duPont)		>10
Nylon		>10
Pentalyn M pentaerythritol ester of resin (Hercules)		50
Polyacrylonitrile, specific viscosity 2.1[c]		24
3.1		18
8.7		10
31.9		5
Poly(methyl α-chloroacrylate)		>10
Poly(methyl methacrylate)		>10
Polybutene		sol
Polystyrene		25
Polyester-type polyurethane rubber (Mobay)	(at 80°C)	10
Polyvinyl chloride		>10
Polyvinyl pyrrolidone		>10
Teflon fluorocarbon resin (duPont)		insol
Vinosol Ester Gum glycol ester of pine resin (Hercules)		10
Vinac polyvinyl acetate (Air Products)		10
Vinylite VYHH, VMCH, and VYNS VC/VAc copolymers (U. C.)		>10
Vinylite NYGL vinyl resin (Union Carbide)		25
Vinylite VYNW vinyl chloride resin (Union Carbide)		15
Zytel nylon molding resin (duPont)	(at 200°C)	25

* ">10" shows that a 10g sample dissolves in 100g M-PYROL at room temperature; other numbers indicate the solubility limit for pourable viscosity. "Sol" indicates a qualitative test only, and "insol" indicates no solubility under test conditions.

[a] Solubility 10% (room temperature) and 25% (80°C).

[b] After 24 hours at 25°C or 1 hour at 60°C, gels.

[c] Sp. Visc. of 1 g polymer in 100 ml M-PYROL at room temp.

Table 14.155: Bunsen Solubility Coefficients for Gases in M-Pyrol Solvent *(49)*

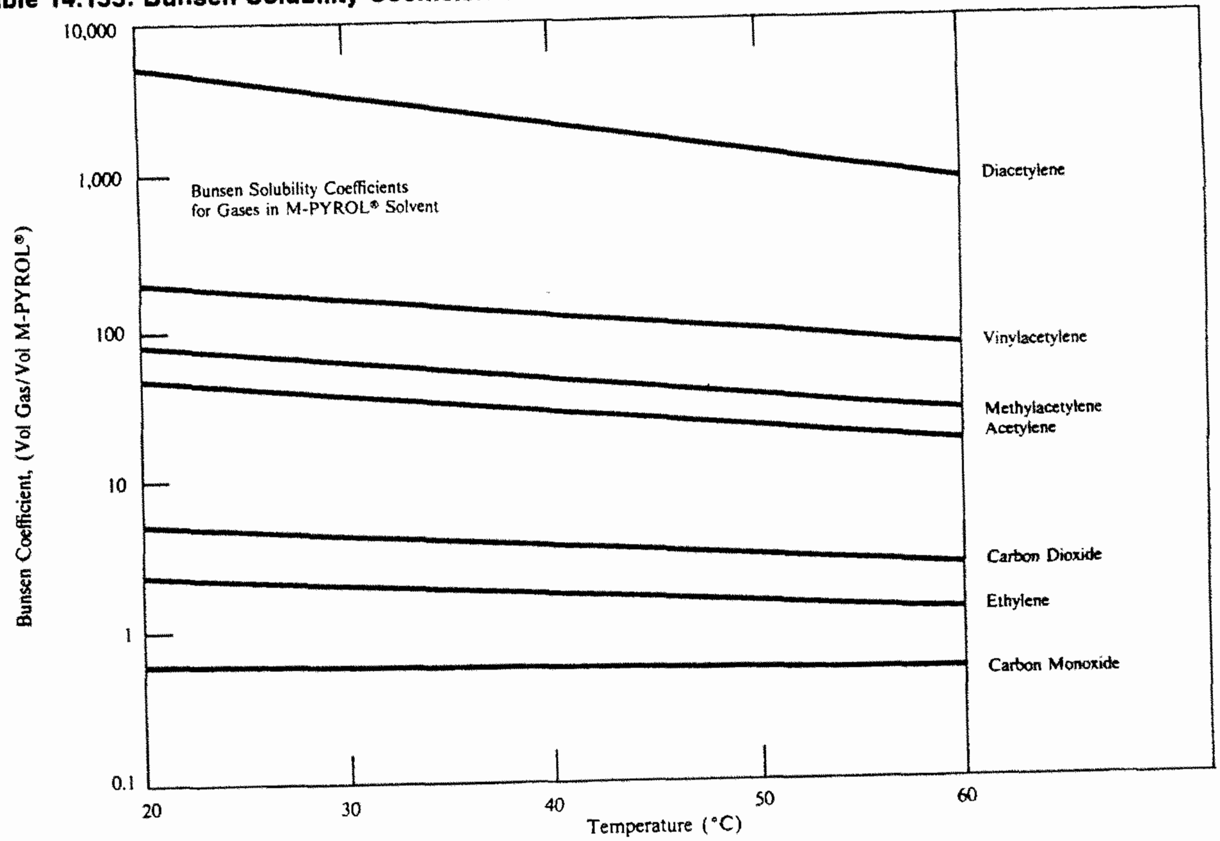


Table 14.156: Solubility in M-Pyrol (to nearest 5%) at Room Temperature *(49)*

Herbicides	2, 4-dichlorophenoxybutyric acid		25%
	butoxyethyl ester		75%
	butyl ester		75%
	isooctyl ester		>80%
	isopropyl N-(3-chlorophenyl) carbamate		>80%
	2-methyl-4-chlorophenoxyacetic acid		>80%
	2, 4, 5-trichlorophenoxyacetic acid		50%
	butoxyethoxypropyl ester		75%
	butyl ester		75%
	isobutyl ester		75%
	isooctyl ester		75%
Insecticides	aldrin	(cloudy)	30%
	chlordane		60%
	DDT		65%
	dieldrin		35%
	O, O-dimethyl-O-(2, 2-dichlorovinyl) phosphate		>80%
	heptachlor	(cloudy)	30%
	lindane		50%
	malathion		>80%
	methyl parathion		>80%
	parathion		80%
	Sevin (Union Carbide)		55%
	toxaphene		50%
Fungicides	captan	(100°C)	33%
	pentachlorophenol		10%
	phenylmercuric acetate		10%

Table 14.157: M-Pyrol Solvent Effects at Ambient Temperature for 7 Days *(49)*

	Percent Change from Initial				
Substrate	Weight	Length	Width	Thickness	Comments
ABS	Coupons fragmented within 1 hr. of immersion				
Buna-N	66.99	17.19	13.47	22.23	Note 1
Butyl Rubber	1.37	0.42	-1.39	0.00	Note 2
EPDM-70	4.14	0.91	-0.32	1.56	Note 1
Kynar	-11.72	3.85	-2.99	19.30	Coupons dissolving
Lexan	Coupons completely dissolved within 18 hours				
Neoprene	0.79	-1.57	-0.45	0.00	Note 1
Noryl EN-265	Coupons completely delaminated within 72 hrs.				
Nylon 101	-0.59	-0.16	-0.19	4.17	Note 2
Polyethylene - Crosslinked	0.09	0.07	0.003	-0.25	Note 2
Polyethylene -Low Density	0.39	0.10	-0.26	0.00	Note 2
Polyethylene - High Density	0.15	0.10	0.06	-0.75	Note 2
Polypropylene	0.02	-0.53	-0.85	1.62	Note 2
PVC	Coupons completely dissolved within 24 hrs.				
Silicon Rubber	1.09	0.16	0.45	0.93	Note 2
Teflon	-0.01	-0.10	0.00	-2.65	Note 2
Viton	176.0	50.28	56.89	64.38	Note 1

Note 1: Coupons discolored, imbibed or continued to leach M-PYROL up to 24 hrs. after removal.
Note 2: No visible effects

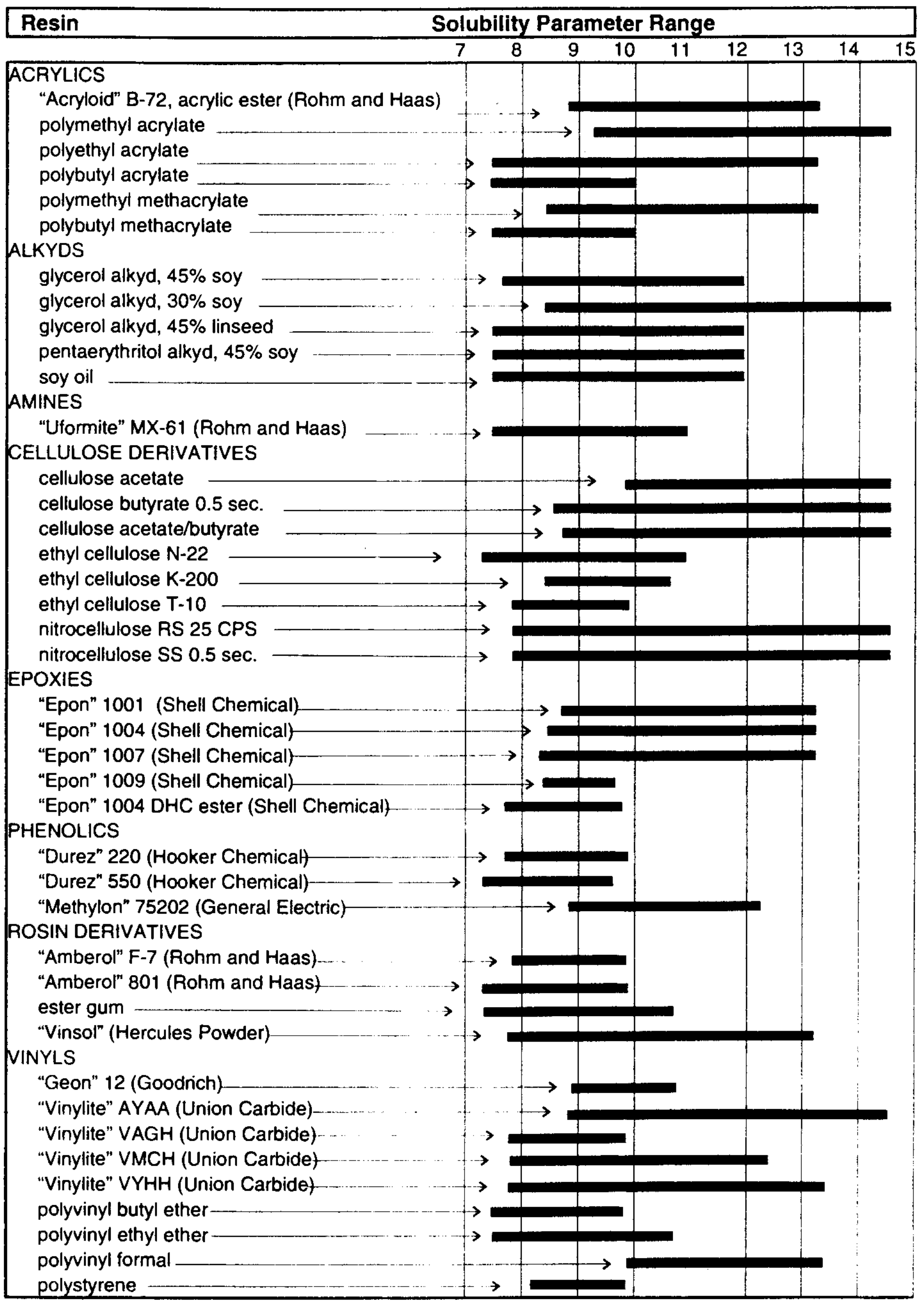
Table 14.158: M-Pyrol Solvent Effects at 70°C for 7 Days *(49)*

	Percent Change from Initial				
Substrate	Weight	Length	Width	Thickness	Comments
Butyl Rubber	6.25	1.60	1.44	0.00	Note 1
EPDM-70	5.88	0.62	1.92	0.00	Note 1
Neoprene	1.71	-0.42	0.78	-2.86	Note 1
Nylon 101	1.65	0.23	0.00	3.03	Note 2
Polyethylene - Crosslinked	1.40	0.13	0.13	1.24	Note 2
Polyethylene -Low Density	1.63	-0.09	0.26	0.00	Note 2
Polyethylene - High Density	0.99	0.20	-0.32	-2.70	Note 2
Polypropylene	1.94	0.30	0.33	1.64	Note 2
Silicon Rubber	2.33	0.65	0.00	2.78	Note 2
Teflon	0.01	0.30	-0.06	0.00	Note 2

Note 1: Coupons discolored, imbibed or continued to leach M-PYROL solvent up to 24 hrs. after removal
Note 2: No visible effects

Table 14.159: Solubility Parameters *(49)*

Comparison of M-PYROL Solvent and Moderately Hydrogen-Bonded Solvents



NOTE: The value for M-PYROL solvent d = 11.0 is based on a total heat of vaporization of 12,200 cal/mol, reference temperature 65°C.

The solubility parameters for resins are based on figures published by Burrell (1957) and Hughes and Britt (1961).

Polystyrene seems to be a notable exception. It is known to be soluble in M-PYROL solvent yet the reported solubility parameter range is only 9.0 ± 0.9 (Burrell 1957).

Table 14.160: Typical Physical Properties of Pyrrolidone Solvents *(49)*

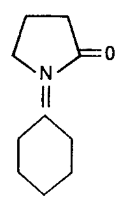
	NEP®	CHP®	HEP®
Physical Form	Liquid	Liquid	Liquid
Molecular Weight	113	167	129
Purity, Area % GC	98% Minimum	98% Minimum	98% Minimum
Moisture, %	0.5 Maximum	0.5 Maximum	0.5 Maximum
Boiling Point, °C	200	284	295
Freezing Point, °C	< −70	12	20
Viscosity, cps 25°C	3.5	11.5	53
Refractive Index @ 25°C	1.4664	1.4950	1.4951
Specific Gravity @ 25°C	0.993	1.026	1.139
Flash Point, Closed Cup (°F)	199	293	320
Heat of Vaporization KCal/mole	12.7	12.9	16
Solubility, Parameter	10.3	8.7	11.7
CAS Registry No.	2687-91-4	6837-24-7	3445-11-2
Chemical Structure			

Table 14.161: Hydrolytic Stability of Alkyl Pyrrolidones *(49)*

Pseudo First Order Rate Constant for Acid Hydrolysis of Selected One Molar Pyrrolidones in Aqueous One Molar HCl at 100°C pH 0.4 ± 0.1

Pyrrolidone Solvent	Pseudo First Order Rate Constant K × 10¹⁰ Sec⁻¹	Hydrolysis Rate t(0.50) Years	Hydrolysis Rate t(0.05) Days
2-PYROL®	44.7 ± 10	1.96	53
HEP®	22.3 ± 5	3.9	105
M-PYROL®	15.2 ± 0.4	5.8	156
NEP®	7.45 ± 1.2	11.7	316
CHP®	1.35 ± 0.09	65	1745

Base Hydrolysis, 1 M NaOH, 100°C

Pyrrolidone Solvent	% Hydrolyzed in 5 Hours
HEP®	64.9
NEP®	53.6
CHP®	0

Acid Hydrolysis of CHP (One Molar) in 2.5 Normal HCl at 80°C

Time (Days)	% Hydrolysis
0	0
0.9	1.24
2.0	6.45
4.3	13.44
5	15.32
6	17.92
8	22.80
12	31.90
16.2	40.50
20	47.4
22	50.8

Table 14.162: CHP/Water System (30:70) Minimum Critical Solution Temperature as a Function of Acid/Base Concentration *(49)*

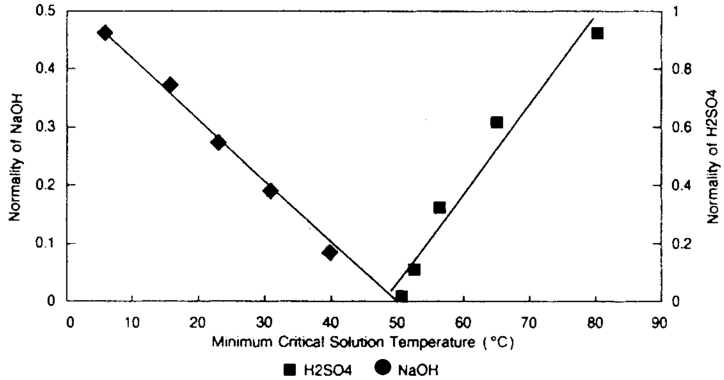


Table 14.163: Phase Diagram CHP Water *(49)*

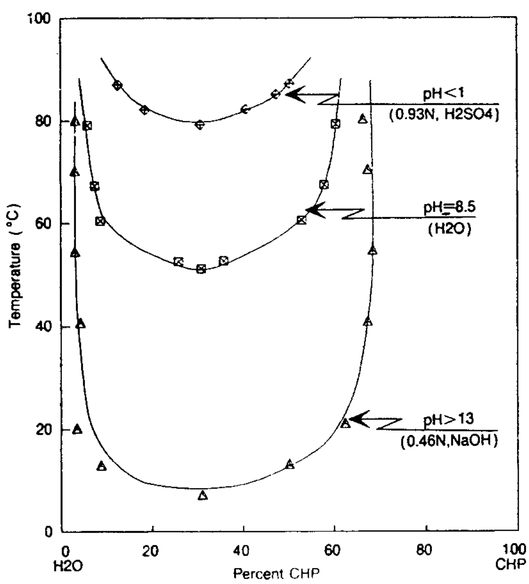


Table 14.164: Minimum Critical Solution Temperature of CHP Water System (30:70) as a Function of Acid/Base Concentration *(49)*

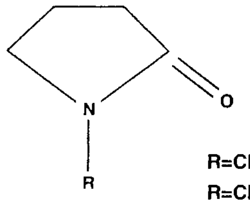
Normality of H_2SO_4, pH < 1	[1]CST (°C)
0.93	79.5
0.6	65.5
0.3	57.0
0.1	52.5
[2]0	50.5
Normality of NaOH, pH > 13	**[1]CST (°C)**
[2]0	50.5
0.09	40.0
0.185	32.0
0.275	23.5
0.37	15.5
0.46	6.0

[1]CST is the minimum temperature below which the system is in one phase for all compositions.
[2]pH = 8.5

Table 14.165: Comparison of NEP, HEP, CHP Solvents with Common Solvents *(49)*

	Freezing Point (°)C	Boiling Point (°)C	Surface Tension dynes/cm 20° cm	Flash Point (°)C	Solubility Parameter
HEP® (N-Hydroxyethyl-Pyrrolidone)	20	295	49	160	11.7
M-PYROL® (N-Methyl-Pyrrolidone)	−24	202	41	95	11.0
NEP® (N-Ethyl-Pyrrolidone)	<−70	200	36	93	10.3
CHP® (N-Cyclohexyl-Pyrrolidone)	12	284	43	145	8.7
DMAC® (Dimethyl-Acetamide) (DuPont)	−20	166	34	70	10.8
DMF® (Dimethyl-Formamide) (DuPont)	−61	153	35	68	12.1

Table 14.166: Surfadone LP Specialty Solvent Structure *(49)*



R=$CH_3(CH_2)_7$ for LP-100
R=$CH_3(CH_2)_{11}$ for LP-300

Table 14.167: Physical Properties of Surfadone LP Products *(49)*

	SURFADONE® LP-100	SURFADONE® LP-300
Physical Form (25°C)	Clear to slightly hazy liquid	Clear to slightly hazy liquid
Boiling Point (°C)	100 (0.3mm Hg)	145 (0.2mm Hg)
Vapor pressure (mm Hg)	0.5×10^{-3}	0.1×10^{-4}
Density (g/cc)	0.92	0.90
Solubility Parameter	9.2	8.9
Flash Point (°C)(TCC)	119	116
Solidification Point(°C)	-25	10
Thermal Gravimetric Analysis (°C)(1)	175	225
Molecular Weight	197	253
Min. Surface Tension (dynes/cm)(2)	28	26

(1) Temperature at which 10% weight loss occurs (by volatilization).
(2) Saturated solution

Table 14.168: Phase Diagrams *(49)*

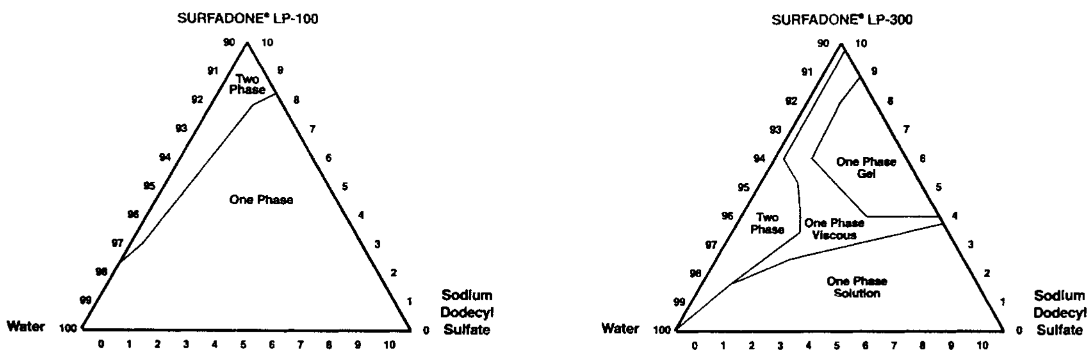


Table 14.169: Solubilities of Surfadone LP 100 and LP-300 Nonionics in Various Solvents *(49)*

Solvent	SURFADONE® LP-100	SURFADONE® LP-300
Water	< 0.1% or > 65%	< 0.002%or > 80%
Ethanol	S	S
Acetone	S	S
Xylene	S	S
Heptane	S	S
Paraffin Oil	S	S
Stoddard Solvent	S	S
Perchloroethylene	S	S

S = soluble at 10%

Table 14.170: Surfactant Properties of Surfadone LP Products *(49)*

Solvent	SURFADONE® LP-100	SURFADONE® LP-300
Maximum concentration in H_2O (%)	0.124	0.002
Minimum static surface tension (dynes/cm)	28	26
Draves wetting time (sec.)	4	300
Dynamic surface tension (dynes/cm)[1]	29	N/A
HLB	6	3

(1) at a surface age of one second

Table 14.171: Low Concentrations of Surfadone LP Products Lower Surface Tension of Water *(49)*

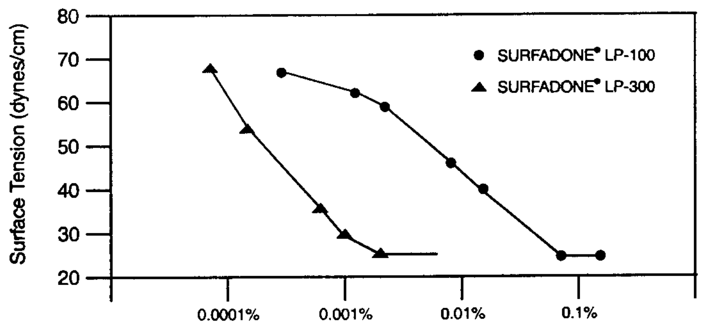
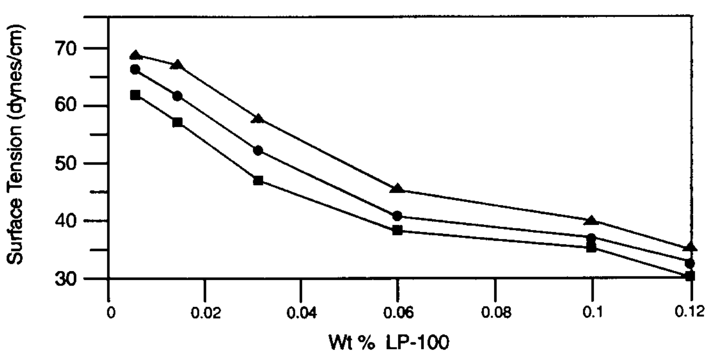


Table 14.172: Draves Wetting Time for Surfadone LP Products with SDS (seconds) *(49)*

	0.1% Solution	with 0.008% SDS	with 0.018% SDS
SURFADONE® LP-100	3.5	2.4	<1
SURFADONE® LP-300	>300	5.4	4.4
SDS	17	—	—

Table 14.173: Low Concentrations of Surfadone LP Products Reduce Dynamic and Equilibrium Surface Tension *(49)*



LP-100 %	Surface Tension (dynes/cm.) Bubbles/sec.		
	1 ■	5 ●	10 ▲
0.007	62	67	69
0.015	57	62	67
0.030	48	52	57
0.060	39	41	45
0.100	35	37	40
0.120	30	32	35

Table 14.174: Surfadone LP Products Effectively Wet Difficult-to-Wet Substrates *(49)*

(Contact Angles in 0.1% Solutions in Water)

	Aluminum	Silicone	Polypropylene	Teflon
Water	84	95	95	113
SURFADONE® LP-100	<5	56	34	54
SURFADONE® LP-300	36	53	33	54

Table 14.175: Surfadone LP/SDS Ratio *(49)*

	Pure	3:1	1:1	1:3
SURFADONE® LP-100	25/5	159/159	164/161	58/157
SURFADONE® LP-300	13/11	139/139	135/135	151/151
Sodium Dodecyl Sulfate (SDS)	156/156	—	—	—

Foam Height (mm), initial/5 min
Total concentration, 0.1%

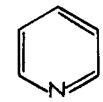
Table 14.176: Elastomer Mechanical Properties—Results of Material Resistance to NMP *(47)*

(6 Weeks Immersion @ 120°F)

MATERIAL	INITIAL WT. (G)	FINAL WT. (G)	Δ WEIGHT	% Δ WEIGHT	DIMENSION BEFORE (CM)	DIMENSION AFTER (CM)	TOTAL LOSS	TOTAL GAIN
1) CELCON*	95.8334	96.7680	0.9346	0.98	3.0 × 11.5 × 1.93	3.0 × 11.5 × 1.56	—	0.026
2) TEFLON*	16.8372	16.8394	0.0022	0.013	3.2 × 10.1 × 0.241	3.2 × 10.1 × 0.241	—	—
3) NYLON (ROD)	15.8448	15.9256	0.0808	0.51	1.3 × 10.2 × 1.300	1.3 × 10.2 × 1.290	0.01	—
4) TIVAR*	28.9250	29.1876	0.2626	0.91	2.6 × 10.2 × 1.204	2.6 × 10.3 × 1.209	—	— × 0.1 × 0.005
5) NYLON (SHEET)	31.0453	31.1811	0.1358	0.44	3.6 × 10.5 × 0.711	3.6 × 10.5 × 0.714	—	0.1 × — × 0.003
6) PVC	17.3684	—	—	—	3.5 × 11.7 × 0.301	—	—	—
7) EPDM	13.5350	12.4198	−1.1152	−8.2	3.8 × 10.2 × 0.331	3.6 × 9.8 × 0.309	0.2 × 0.4 × 0.022	—
8) NEOPRENE (R-30)	17.7365	23.5720	6.8355	39.0	4.0 × 10.4 × 0.354	—	—	—
NEOPRENE (R-30)	17.7365	18.2105	0.4740	2.7	4.0 × 10.4 × 0.354	3.9 × 10.4 × 0.324	0.1 × — × 0.03	—
9) GUM RUBBER	27.2070	31.9650	4.7580	17.5	4.0 × 10.3 × 0.683	4.3 × 10.3 × 0.719	—	0.3 × 0.5 × 0.036
10) NEOPRENE (R-41)	8.2889	9.1755	0.8866	10.7	3.9 × 10.1 × 0.165	—	—	—
NEOPRENE (R-41)	8.2889	7.1048	−1.1841	−14.3	—	3.6 × 9.5 × 0.160	0.3 × 0.6 × 0.005	—
11) BUTYL RUBBER	39.1515	40.8792	1.7277	4.4	4.4 × 10.2 × 0.640	4.4 × 10.3 × 0.665	—	— × 0.1 × 0.025
12) MYLAR*	0.6565	0.7224	0.0659	10.0	3.9 × 10.1 × 0.013	3.8 × 10.2 × 0.013	—	—
13) VITON*	12.2540	25.5317	13.2777	108.0	4.0 × 10.3 × 0.162	—	—	—
VITON*	12.2540	14.2267	1.9727	16.1	4.0 × 10.3 × 0.162	4.4 × 11.0 × 0.134	—	0.4 × 0.7 × 0.03
14) HYPALON*	9.0964	10.3928	1.2964	14.3	3.9 × 10.2 × 0.170	—	—	—
HYPALON*	9.0964	8.2690	−0.8274	−9.1	3.9 × 10.2 × 0.170	3.7 × 9.8 × 0.167	0.2 × 0.4 × 0.003	—
15) SILICONE	8.1632	8.2814	0.1182	1.45	4.2 × 10.3 × 0.158	4.2 × 10.3 × 0.157	0.001	—

Detailed information is available in a separate technical report.

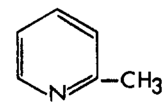
Table 14.177: Pyridine *(2)*



Pyridine is a liquid miscible with water, alcohol, ether, benzene and many organic liquids. It is an excellent solvent for organic materials and will dissolve many metallic salts giving comparatively stable compounds (without substitution). It is used in the preparation of water-proofing chemicals, rubber accelerators, and pharmaceuticals. It is also used as an extractant and in distilling and purifying operations. The less pure grade is used as a denaturant for industrial alcohol.

Boiling point	115°C
Melting point	−42°C
Specific gravity at 25/4°C	0.978

Table 14.178: Alpha-Picoline *(2)*

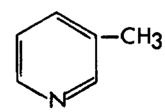


2-Methyl Pyridine

Alpha-picoline is a liquid which is very soluble in water, forming a constant-boiling mixture with it. It is also soluble in ethyl alcohol and ethyl ether. It may be used in the manufacture of alkaloids, pharmaceuticals, antioxidants, and rubber accelerators.

Boiling point	128°C
Melting point	−69.9°C
Specific gravity at 15/4°C	0.950
Distillation Range	Completely within 2°C

Table 14.179: Beta-Picoline *(2)*

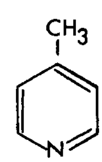


3-Methyl Pyridine

Beta-picoline is similar to the alpha compound. It is soluble in water with which it forms a constant-boiling mixture; it is also soluble in ethyl alcohol and ethyl ether. Suggested uses for it are in the manufacture of alkaloids, pharmaceuticals and rubber accelerators. It is also a starting material for the production of nicotinic acid and nicotinic acid amide.

Boiling point	143.5°C
Melting point	−18.3°C
Purity	95%, min.
Specific gravity at 15/4°C	0.961

Table 14.180: Gamma-Picoline *(2)*

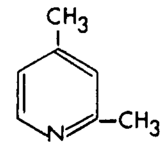


4-Methyl Pyridine

The solubility and uses for this solvent are similar to those of the alpha and beta compounds.

Boiling point	143.1°C
Melting point	+3.8°C
Purity	95%, min.
Specific gravity at 15/4°C	0.957

Table 14.181: 2,4-Lutidine *(2)*



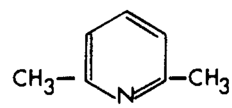
2,4-Dimethyl Pyridine

2,4-Lutidine is a liquid, very soluble in alcohols, ketone, ethers, hydrocarbons, and most organic solvents, but only 15% soluble in water. It is recommended for use in the synthesis of drugs, dyes, and other chemicals.

Boiling point	158.3°C
Distillation	90% distills within 2°C
Freezing point	Below −60°C
Specific gravity at 25/4°C	0.927

Table 14.182: 2,6-Lutidine *(2)*

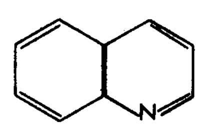
2,6-Dimethyl Pyridine



2,6-Lutidine is a liquid, very soluble in water, alcohols, ethers, ketones, hydrocarbons, and most organic solvents. It is recommended for use in the manufacture of resins, dyes, drugs, insecticides, rubbers, and organic chemicals.

Boiling point	142.9°C
Freezing point	−6.0°C
Purity	95%, min.
Specific gravity at 25/4°C	0.928

Table 14.183: Quinoline *(2)*



Quinoline is a liquid, soluble in alcohol, ether, carbon disulfide, and in most of the common organic solvents, but only partially soluble in water. It is a solvent for cellulose esters and ethers when used with other solvents. It is used in the manufacture of dyes, photographic sensitizers, nicotinic acid, and drugs. It is also used as an extraction agent and in organic synthesis.

Boiling point	237.7°C
Melting point	−19.5°C
Specific gravity at 20/4°C	1.095
Distillation range	95% distills within 2°C

Table 14.184: 2-Methyl-5-Vinyl Pyridine *(4)*

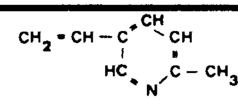
FORMULA		
PROPERTIES		
Purity, mol percent (water-free basis)	95.1	94.0 min * •
Boiling point, at 50 mm Hg, F	212	
at 160 mm Hg, F	358	
Freezing point, C (water-free basis)	−14.16	−15.14 min
Water content, weight percent	0.20	0.5 max
Refractive index at 25 C	1.541	
Specific gravity of liquid at 60/60 F	0.962	
Density of liquid at 60 F, lbs/gal	8.01	
Color, Gardner	1	2 max
Appearance	Clear	
Polymer content (Hexane Dilution)	Negative	Negative min
Flash point, F (TOC)	165	
Inhibitor content, weight percent (Tertiary Butyl Catechol)	0.1	0.05 min – 0.15 max

Table 14.185: 1,2,4-Trimethylpiperazine *(47)*

TYPICAL PHYSICAL PROPERTIES

Form	Liquid
Viscosity at 25°C.	1.037 cps.
pH, 1% Aqueous Solution	10.3
Boiling Point (746 mm)	149° - 151°C.
Freezing Point	<-50°F.
Specific Gravity 25/25°C.	0.851
Refractive Index at 25°C.	1.4480
Fire Point, Cleveland Open Cup	125°F.
Pour Point	<-50°F.

SOLUBILITY

Soluble in water, acetone, methanol and benzene.

AVAILABILITY

1,2,4-trimethylpiperazine is available in semi-commercial quantities.

Table 14.186: 1,4-Bis(2-Hydroxypropyl)-2-Methylpiperazine (DHP-MP) *(47)*

TYPICAL PHYSICAL PROPERTIES

Form	Liquid
Viscosity, 25°C.	752 cps.
Boiling Point (3 mm.)	145°C.
Pour Point	10°F.
Specific Gravity 25/25°C.	1.001
Refractive Index, 25°C.	1.4803
Flash Point, Open Cup	300°F.
Color	Light Yellow
Molecular Weight	216
pH, 1% Aqueous Solution	10.0
Analysis, based on tertiary nitrogen content	97%

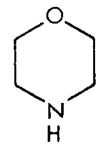
SOLUBILITY

Miscible in all proportions with water, acetone, ethanol, benzene, heptane, and carbon tetrachloride.

Table 14.187: Morpholine *(48)*

Tetrahydro-p-Oxazine

Molecular weight: 87.12



This commercially important secondary amine is a water-white, mobile liquid having an ammoniacal odor. It is very soluble in water and forms a stable solution which exhibits a constant composition during evaporation and distillation as well as preserving a constant alkalinity. The ring structure of this solvent, as well as its ether and amine groups, gives it unique solvent power for a greater than usual variety of organic substances, among which are resins, dyes, waxes, shellac, and casein.

It is used in permanent wave solutions for its mild alkalinity; in soaps which are emulsifying agents for paper coatings; in rubless polishes, lacquers, paints, insecticides, etc. It imparts water-resistance after drying. Its water-soluble salts have high phenol coefficients. Morpholine may also be used in photographic developing.

Color, Pt - Co scale	15 max.
Boiling range, °C	
IBP	125.0 min.
DP	132.0 max.
Purity, wt.%	98.0 min.
Specific gravity, 20/20°C	0.999 - 1.004
Suspended matter	Substantially free
Freezing point, °C	-4.9
Boiling point, °C	128.9
Flash point, (TOC) °C	38
°F	100
Density, g./cc. at 20°C	0.9994
Refractive index, n_D^{20}	1.4545
Surface tension, dynes/cm. at 20°C	37.5
Viscosity, centipoises at 20°C	2.23
Conductivity, mho/cm. x 10^{10}	6
pK_b	9.61
Dielectric constant	7.33
Dipole moment, Debyes	1.58
Molar polarization, P_∞ in benzene	75.3
Heat capacity, cal./mol./deg. at 25°C	41.6
Heat of vaporization, cal./mol. (45-129°C)	9510

Table 14.188: Boiling Point Composition Curves for Aqueous Morpholine Solutions *(19)*

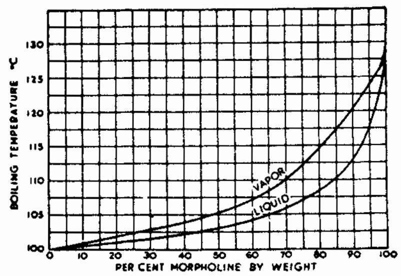


Table 14.189: pH of Aqueous Morpholine Solutions at 25°C *(19)*

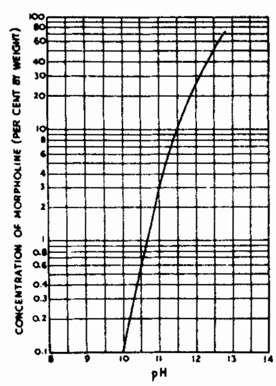


Table 14.190: Viscosity of Aqueous Morpholine Solutions at 20°C *(19)*

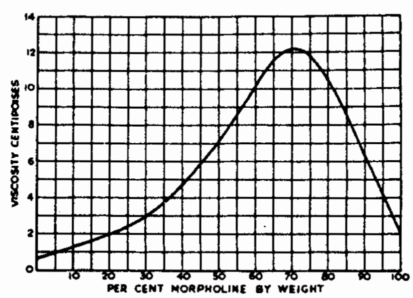
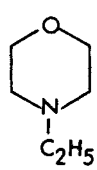


Table 14.191: Solubility of Various Substances in Morpholine *(48)*

Substance	g. Solute in 100 g. Morpholine at 25°C	Substance	g. Solute in 100 g. Morpholine at 25°C
Acetone	∞	2-Hexanone	∞
Beeswax	< 1	Linseed oil	∞
Benzene	∞	Methanol	∞
Benzyl cellulose	> 5	Methylamine	33
Butyl ether	∞	Methylcyclohexanol	∞
Castor oil	∞	Naphtha	> 5
Cellulose acetate	> 5	Paraffin oil	< 1
Cellulose nitrate	> 5	Paraffin wax (hot)	> 5
Copal gum	> 5	Pine oil	∞
Dimethylamine	109	Resin	> 5
Ester gum	> 5	Shellac	> 5
Ethanol	∞	Sulfur	< 5
2-Ethylbutanol	∞	Trimethylamine	34
Ethylene glycol	∞	Turpentine	∞
Ethyl ether	∞	Polyvinyl acetate	> 5
Glycol ether	∞	Polyvinyl butyral	> 5
		Polyvinyl chloride	> 5

Table 14.192: N-Ethyl Morpholine *(2)*

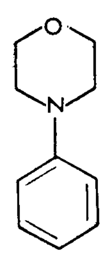


This cyclic tertiary amine is a water-white liquid miscible with water. It may be used as a solvent for oils, dyes and resins, and as an intermediate in the synthesis of rubber accelerators, emulsifying agents, drugs, and dyes.

Boiling Point . . . . 138°C.

Specific Gravity at 20/20°C. . . . 0.916

Table 14.193: N-Phenyl Morpholine *(2)*



Boiling Point at 760 mm. . . . . . . 268°C.

Melting Point . . . . 57°C.

Esters

FORMATES

Table 15.1: Methyl Formate *(2)*

$HCOOCH_3$

Methyl formate is a colorless flammable liquid with a pleasant ethereal odor. It will dissolve cellulose ethers and esters but will dissolve them more readily when mixed with other solvent esters or the less volatile halogenated hydrocarbons.

Acidity	Neutral to methyl orange (methyl formate hydrolyzes in presence of water)
Boiling point	31.8° C
Color	Water-white
Distillation range	Below 31.5°C None
	Above 35.0°C None
Electrical conductivity at 25°C	3.6×10^{-6} reciprocal ohms
Flash point	−32°C
Melting point	−99.8°C
Odor initial	Pleasant, ethereal
Odor residual	Non-residual
Purity	95% to 100% ester, by wt
Refractive index at 20°C	1.3431
Solubility in water at 20°C	30% by vol
Solubility of water in solvent at 25° C	24% by vol
Specific gravity at 20/20°C	0.950 to 0.980
Vapor pressure	
0°C	195.0 mm of Mercury
10°C	309.4 mm of Mercury
16°C	400.0 mm of Mercury
20°C	476.4 mm of Mercury
25.8°C	600.0 mm of Mercury
30°C	707.9 mm of Mercury

Table 15.2: Ethyl Formate *(2)*

Formosol $HCOOC_2H_5$

Ethyl formate is a water-white, highly volatile and unstable liquid with a pleasant odor resembling peach kernels. It is partly soluble in water and miscible with benzene. It is a powerful solvent for cellulose nitrate and acetate, yielding solutions of unusual low viscosity which have a tendency to chill. It is an important fumigant and larvicide for the treatment of tobacco, cereals, dried fruit and similar products. It is used as a chemical intermediate in the manufacture of such medicinals as sulfadiazine, thiamin (Vitamin B_1), and perfumes and synthetic flavors.

(continued)

Table 15.2: (continued)

Acidity	Neutral to methyl orange (it hydrolyzes in the presence of water)
Boiling point	54.3°C
Color	Water-white
Distillation range	51°-55°C
Electrical conductivity at 25°C	Less than 1.45×10^{-9} recip ohms
Flash point	−19°C
Freezing point	−80.5°C
Purity	95% to 100%
Refractive index at 20°C	1.3604
Specific gravity at 20/20°C	0.900 to 0.930
Solubility in water at 20°C	10% by vol
Solubility of water in solvent at 20°C	17% by vol
Vapor pressure at 20.6°C	200 mm of Hg
at 30.2°C	300 mm of Hg
Weight per gal at 68°F	7.61 lbs

Table 15.3: Butyl Formate *(2)*

$$HCOOCH_2CH_2CH_2CH_3$$

Butyl formate is a colorless liquid, miscible with alcohols, ethers, oils, hydrocarbons and so forth. It will dissolve cellulose nitrate, some types of cellulose acetate, and many cellulose ethers. Butyl formate will also dissolve many natural and synthetic resins such as copals, dammar, elemi, mastic, shellac, cumar resins, ester gum and alkyds in the presence of ethyl alcohol. It is used as an intermediate and in perfumes.

Acidity	0.02% max.
Ester content	85% min.
Boiling range	96°-110°C.
Specific gravity	0.885-0.9108

Table 15.4: Amyl Formate *(2)*

$$HCOOC_5H_{11}$$

Commercial amyl formate is an anhydrous, colorless liquid composed of a mixture of isomeric amyl formates with the isoamyl formate in predominance. This mixture is miscible with oils, hydrocarbons, alcohols, ketones and so forth. It is a solvent for cellulose esters, "Cumar", copal, gum esters, etc. It is able, when mixed with an alcohol, to dissolve shellac and alkyd resin. It is a less odoriferous and more energetic solvent than amyl acetate. It also has both a lower boiling point and a greater speed of evaporation. n-Butyl acetate and amyl formate have similar volatility and have substantially the same solvent power which permit free interchange of these only as far as these properties allow.

Acidity	0.05% max.
Boiling point	130.4°C.
Boiling range	110°-130°C.
Flash point	80°F.
Specific gravity	0.880-0.885

ACETATES

Table 15.5: Methyl Acetate *(2)*

CH_3COOCH_3

Methyl acetate is a water-white flammable, readily hydrolyzable liquid, with a fragrant odor. This low-boiling solvent was first prepared in 1835 by reacting acetic acid and methanol. It is miscible with most organic solvents and will completely dissolve cellulose nitrate and acetate, ethyl cellulose, resins such as ester gum, rosin, "Cumar", elemi, phenolics, and oils such as corn, linseed, castor, neatsfoot, chinawood and cottonseed. It will only partially dissolve shellac, manila, dammar, pontianac, Beckacites and alkyds. In many respects, methyl acetate resembles acetone as a solvent, particularly as to its boiling point, solvent power and miscibility, but its tendency to hydrolyze to methanol and acetic acid, in the presence of water, limits its wider use in the industries. Methyl acetate is usually admixed with higher boiling solvents. It is used in lacquers, paints, varnishes, enamels, perfumes, dyes, dopes, plastics, and synthetic finishes as well as a substitute for acetone.

Acidity (as acetic)	0.005%, max	Freezing point	−98.1°C
Boiling point	56.9°C	Heat of combustion	5371 cal/g
Distillation range	55–58°C	Heat of vaporization	104.4 cal/g
Coefficient of expansion (per °C) at 20°C	0.001390	Non-volatile matter	0.005 gram per 100 cc, max
Color	Water-white	Refractive index at 20°C	1.3593
Critical temperature	233.7°C	Solubility in water at 20°C	24% by wt
Critical pressure	46–3 atm	Solubility of water in solvent at 20°C	8% by wt
Dielectric constant at 20°C	7.3 ± 0.2	Specific gravity at 20/20°C	0.9353
Dilution ratios		Surface tension at 20°C	24.6 dynes/cm
Toluene	2.9	Vapor pressure at 20°C	173 mm Hg
Petroleum naphtha	0.9	Viscosity at 20°C	0.00381 poises
Electrical conductivity at 25°C	3.4 × 10^{-6} mho	Weight per gal at 20°C	7.783 lbs
Flash point (A.S.T.M. Open Cup)	−15°C		

Table 15.6: Ethyl Acetate *(2)*

Acetic Ether $CH_3COOC_2H_5$

Ethyl acetate is a water-white, flammable liquid with a pleasant, fruity odor. The 85 to 88 per cent grade of ethyl acetate suitably denatured is generally used for commercial purposes but 95 and 99 percent grades are also available. It is miscible with most organic solvents such as alcohols, ketones, esters, aromatic, aliphatic and halogenated hydrocarbons. It dissolves such materials as nitrocellulose, camphor, oils, fats, waxes, gums and natural and synthetic resins. It will tolerate fairly large amounts of lacquer diluents and like methyl acetate it not only has a wide range of solubilities but it possesses the unique property of dissolving nitrocellulose, cellulose acetate and cellulose ethers yielding solutions of low viscosity. Its solvent power for cellulose derivatives is much improved, however, by adding a small quantity of alcohol.

(85 to 88%)

Acidity (as acetic acid)	0.01% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 45% Relative humidity Bluish 50%
Coefficient of cubical expansion (ordinary temperatures)	0.00073 per °F 0.00132 per °C
Color	Water-white
Critical temperature	250.1°C
Critical pressure	37.8 atmospheres
Dilution ratio	
Toluol	3.5
Petroleum naphtha	1.1
Distillation range	Below 70°C None Below 72°C Not more than 10% Above 80°C None
Dryness	Miscible without turbidity with 20 volumes 60° Bé gasoline at 20°C
Electrical conductivity at 25°C	Less than 1 × 10^{-6} reciprocal ohms
Evap. rate at 95°F (in min.)	
5%	¼
25%	1½
50%	3¼
75%	6¼
90%	9½
95%	11¼
Flash point	−5°C (23°F)
Freezing point	−82.4°C
Non-volatile matter	0.003 gram per 100 cc, max
Refractive index at 20°C	1.3725
Solubility in water at 25°C	9.7% by vol
Solubility of water in solvent at 25°C	9.8% by vol
Specific gravity at 20/20°C	0.883 to 0.888
Viscosity at 20°C	4.546 millipoises
Weight per gal at 68°F	7.36 lbs

(95 to 98%)

Acidity (as acetic)	0.01% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 50% Relative humidity Blush 55%
Coefficient of expansion per 1°F	0.00074
per 1°C	0.00133
Color	Water-white
Dilution ratio	
Toluol	3.2
Petroleum hydrocarbon	1.0
Distillation range	74 to 80°C
Dryness at 20°C	Miscible without turbidity with 20 vol 60° Bé gasoline

(continued)

Table 15.6: (continued)

	(95 to 98%)
Evap. rate at 95°F (in min.)	
5%	¼
25%	1½
50%	3½
75%	6
90%	7¾
95%	8½
Flash point	26°F (approximate)
Non-volatile matter	0.003 gm per 100 cc, max
Solubility of water in solvent at 25°C	4% by vol
Specific gravity at 20/20°C	0.895 to 0.900
Viscosity (10% ½ sec. nitrocellulose solution)	33 centipoises
Water	No turbidity when mixed with 19 volumes of 60° Bé gasoline at 20°C
Weight per gal at 20°C	7.47 lbs
	(99 to 100%) acetic ether grade
Acidity (as acetic)	0.01% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 55% Relative humidity Blush 60%
Coefficient of expansion per 1°F	0.00074
per 1°C	0.000133
Color	Water-white
Dilution ratio	
Toluol	3.0
Petroleum naphtha	1.0
Distillation range	75 to 80°C
Electrical conductivity at 25°C	3.2 × 10^{-7} recip ohms
Evap. rate at 95°F (in min.)	
5%	½
25%	1½
50%	3¾
75%	6½
90%	9½
95%	10½
Explosive limits	2.26–11.4%
Flash point	0.5°C
Freezing point	−82.4°C
Heat of combustion	538 kg. cal/mole
Heat of vaporization at 0°C	102 cal/gm
at 80°C	102.9 cal/gm
Non-volatile matter	0.003 gram when 100 cc, max

Table 15.7: n-Propylacetate *(41)*

$$CH_3COOC_3H_7$$

The properties of n-propyl acetate are, approximately, intermediate between those of ethyl and n-butyl acetates. It is miscible with alcohols, ketones, esters, oils and hydrocarbons and is a good solvent for nitrocellulose and a wide range of cellulose derivatives, especially when it is admixed with the aromatic hydrocarbons or the lower aliphatic alcohols. It will also dissolve natural and synthetic resins like elemi, "Cumar" resins, ester gum, manila, mastic, rosin and sandarac. It is used principally as a low-boiling component in nitrocellulose lacquer formulations.

Molecular Weight (Theoretical)	102.08
Color (Pt-Co Scale), max	15
Weight/Vol, 20°C,	
lb/gal (U.S.)	7.39
kg/liter	0.89
lb/gal (Imperial)	8.87
Solubility, 20°C, wt %	
In water	2.3
Water in	2.6
Evaporation Rate (n-butyl acetate = 1)	2.3
Dilution Ratio, toluene	3.2
VM & P naphtha	1.5
Refractive Index, 20°C	1.3844
Vapor Pressure, 20°C, mm Hg	23
Specific Gravity, 20°/20°C	0.885
Boiling Range, 760 mm, °C	
Initial Boiling Point, min	99
Dry Point, max	103
Freezing Point, °F (°C)	-131 (-93)
Flash Point, Tag Closed Cup, °F (°C)	55 (13)
Tag Open Cup, °F (°C)	58 (14)
Fire Point, °F (°C)	70 (21)
Flammable Limits in Air, % by volume	
Lower, at 100°F (38°C)	1.71
Upper, at 200°F (93°C)	7.95
Autoignition Temperature (ASTM D-2155), °F (°C)	855 (457)
NFPA Classification 30:	IB
ICC Labels Required	Red
Bureau of Explosives Classification	Flammable Liquid

Table 15.8: Isopropyl Acetate *(2)*

$CH_3COOCH(CH_3)_2$

Isopropyl acetate is a water-white pleasant-odored liquid with properties intermediate between ethyl and butyl acetates. It is miscible with most of the common organic solvents such as alcohols, ketones, esters, oils, hydrocarbons, etc., and it is a solvent for nitrocellulose, cellulose acetate (of low viscosity) and a wide range of oils, fats, waxes, gums and natural and synthetic resins. Like n-propyl acetate, its solvent power for cellulose esters is increased when lower aliphatic alcohols are added. It is largely used in the lacquer industry where its slow evaporation rate and blush resistance are of importance. It is also used in the manufacture of plastics, artificial leather, dopes, films, cements, and in the recovery of acetic acid from aqueous solutions.

Acidity (as acetic)	0.02% by wt, max	Flash point (Tag Closed Cup)	39°F
Boiling point at 760 mm	88.6°C	Freezing point	−73.4°C
Coefficient of expansion per °F	0.000727	Heat of vaporization	79.4 cal/gm
Color	Water-white	Non-volatile matter	2 mg per 100 cc, max
Dilution ratios		Refractive index, N 20/D	1.3772
Toluene	2.7	Solubility of water in solvent	3.2% by wt
V.M. and P. naphtha	0.92	Specific gravity at 20/20°C	0.866 to 0.871
Distillation range	84.5-90°C	Specific heat at 15-25°C	0.521 cal/gm
Electrical conductivity at 25°C	5.7×10^{-7} recip ohms	Surface tension at 25°C	24.5 dynes/cm
Evaporation rate at 95°F (in minutes)		Vapor pressure at 10°C	26.2 mm Hg
5%	$\frac{1}{2}$	20°C	45.7 mm Hg
25%	$1\frac{3}{4}$	30°C	76.1 mm Hg
50%	$4\frac{1}{4}$	40°C	121.8 mm Hg
75%	$7\frac{1}{2}$	Viscosity at 20°C	0.00525 poises
90%	$10\frac{1}{4}$	Weight per gallon at 20°C	7.23 lbs
95%	$11\frac{1}{4}$		

Constant Boiling Mixtures

			% by Wt	B.P. -C
Isopropyl Acetate	47.7	Isopropanol	52.3	80.1
Isopropyl Acetate	89.4	Water	10.6	76.6

Table 15.9: n-Butyl Acetate *(2)*

$CH_3COOCH_2CH_2CH_2CH_3$

This ester is a water-white liquid with a characteristic fruity odor which is less pronounced than the odor of amyl acetate. It is miscible with alcohols, ketones, esters and most of the common organic solvents. It is a solvent for nitrocellulose and cellulose ethers, especially when previously mixed with active or latent solvents. It will dissolve oils, fats, waxes, metallic resinates, camphor, "Cumar" resins, dammar, ester gum, elemi, kauri, manila, mastic, pontianac, rosin, sandarac, chlorinated rubber, and such synthetic resins as the vinyls, polystyrene, and acrylates. In combination with 20 per cent of butyl alcohol, butyl acetate will dissolve the less highly polymerized alkyd resins and shellac. Owing to its power of imparting low viscosity, gum compatibility, and good working qualities, it is classed among the best medium boiling solvents for nitrocellulose. Its volatility meets the demands of a lacquer solvent because it is sufficiently high to leave the film readily and at the same time low enough to prevent blushing. When combined with butyl alcohol it will prevent gum-blush, cotton-blush and chilling. Its largest use is as a solvent in the manufacture of nitrocellulose lacquers for protective coatings, artificial leather and coated paper, plastics, polishes, safety glass, in perfumes, and flavoring materials.

(continued)

Table 15.9: (continued)

	88-92%
Acidity (as acetic)	0.01% by wt, max
Boiling point at 760 mm Hg	126.5°C
Coefficient of cubical expansion (ordinary temperatures)	0.00067 per°F
	0.00121 per°C
Color	Water-white
Dielectric constant at 20°C	5.0
Dilution ratio	
Toluol	2.9
Petroleum naphtha	1.4
Distillation range	Below 115°C None
	Below 120°C Not more than 8%
	Above 130°C Not more than 5%
	Above 135°C None
Evaporation rate at 95°F (in minutes)	
5%	1¼
25%	6¾
50%	13¾
75%	22¼
90%	3¼
95%	34¼
Flash point	28°C
Heat of vaporization	73.8 calories per gm
Freezing point	−76.8°C
Non-volatile matter	0.005 gram per 100 cc, max
Residue	None
Refractive index at 20°C	1.3947
Solubility in water at 25°C	0.5% by vol
Solubility of water in solvent at 25°C	1.6% by vol
Specific gravity at 20/20°C	0.872 to 0.880
Vapor pressure at 0° C	3.0 mm Hg
25°C	15.0 mm Hg
50°C	45.0 mm Hg
Viscosity at 25°C	0.671 centipoises
Weight per gallon at 20°C	7.28 lbs

	98-100%
Acidity (as acetic)	0.01% by wt, max
Boiling point	126.5°C
Coefficient of expansion per 1°F	0006
per 1°C	0.0011
Color (A.P.H.A.)	10 max
Dilution ratio	
Toluol	3.05
Petroleum naphtha	1.40
Distillation range	123°-128°C
Electrical conductivity at 25°C	13×10^{-9} recip ohms
Flash point	82°F approx
Fractionation: I.P.	114.3°
10%	116.0
25%	116.9
50%	117.4
75%	117.6
90%	117.6
E.P.	118.1
Heat of vaporization	73.8 cal/gm
Non-volatile matter	Negligible
Refractive index at 20°C	1.3951
Solubility in water at 25°C	0.78% by wt
Solubility of water in solvent at 25°C	2.88% by wt
Specific gravity at 20/20°C	0.879 to 0.883
Specific heat at 21-27°C	0.505 cal/gm
Surface tension at 27°C	27.6 dynes/cm
Vapor pressure at 20°C	9.0 mm Hg
Viscosity at 25°C	0.00693 poises
Weight per gallon	7.76 lbs

Constant Boiling Mixtures

	% by Wt		% by Wt	B.P. °C
n-Butyl acetate	54.0	*n*-Butanol	46.0	118.0
n-Butyl acetate	60.0	*n*-Propanol	40.0	94.2
n-Butyl acetate	48.0	Isopropanol	52.0	80.1
n-Butyl acetate	71.3	Water	28.7	90.2

Ternary Mixtures

		B.P.
n-Butyl acetate	35.3%	
n-Butanol	27.4%	89.4°C
Water	37.3%	

Table 15.10: sec-Butyl Acetate *(2)*

$$CH_3COOCH(CH_3)CH_2CH_3$$

sec-Butyl acetate is a colorless, flammable liquid with a fruity odor. It is miscible with castor and linseed oils and hydrocarbons, and will dissolve nitrocellulose, cumarone, elemi, ester gum, kauri, mastic, manila, pontianac, asphalt and tar. It has only partial solubility for dammar and shellac. Its solvency is very similar to n-butyl acetate but it has a lower boiling range, less blush resistance and will evaporate with greater rapidity. For this reason, to replace n-butyl acetate it is necessary that this solvent should be mixed with slower evaporating solvents that can make up for its quicker rate of evaporation. It is largely used in the manufacture of nitrocellulose lacquers and similar types of coatings used in airplane dopes, artificial leather, celluloid products, coated paper, patent leather, and textile sizing and printing compounds.

Acidity (as acetic)	0.03% by wt, max
Blush resistance at 60°F	Clear 75% Relative humidity
	Blush 80%
Coefficient of expansion per 1°F	0.00063
per 1°C	0.00113
Color	Water-white
Distillation range:	
Below 104°C	None
Below 111°C	Not more than 10%
Below 114°C	Not more than 60%
Below 118°C	Not less than 90%
Above 130°C	None

(continued)

Table 15.10: (continued)

Evaporation rate at 95°F (in minutes)	
5%	½
25%	3¾
50%	8½
75%	13½
90%	16¾
95%	18
Flash point	66°F
Non-volatile matter	0.005 gm per 100 cc, max
Residue	None
Refractive index, N 25.3/D	1.3866
Specific gravity at 20/20°C	0.862–0.866
Solubility in water	0.74% by wt
Solubility of water in solvent at 25°C	2.1% by wt
Weight per gal at 20°C	7.19 lbs (approx.)

Table 15.11: Isobutyl Acetate *(41)*

$CH_3COOCH_2CH(CH_3)_2$

Isobutyl acetate is a medium-boiling solvent, colorless and with a mild, fruity ester odor. The commercial grade has an ester content of 88 to 92 percent, the balance being substantially isobutyl alcohol. The solvent power of this ester is similar to the normal and secondary acetates. It is miscible with most organic solvents and will dissolve a large number of oils, waxes and natural and synthetic resins. With the limitation set by Rule 66 on the use of branched chain ketones and aromatic solvents, isobutyl acetate is an economical replacement for MIBK and by having a similar evaporation rate, can be formulated in toluene replacements.

Molecular Weight ($C_6H_{12}O_2$)	116.2
Color (Pt-Co Scale), max	10
Weight/Vol, 20°C,	
lb/gal (U.S.)	7.25
kg/liter	0.87
lb/gal (Imperial)	8.70
Solubility, 20°C, wt %	
In water	0.7
Water in	1.6
Evaporation Rate (n-butyl acetate = 1)	1.4
Dilution Ratio, toluene	2.7
VM & P naphtha	1.1
Refractive Index, 20°C	1.3997
Vapor Pressure, 20°C, mm Hg	12.5
Specific Gravity, 20°/20°C	0.870
Boiling Range, 760 mm, °C	
Initial Boiling Point, min	112
Dry Point, max	119
Freezing Point, °F (°C)	-146 (-99)
Flash Point, Tag Closed Cup, °F (°C)	69 (20)
Tag Open Cup, °F (°C)	75 (24)
Fire Point, °F (°C)	88 (31)
Flammable Limits in Air, % by volume	
Lower, at 200°F (93°C)	1.27
Upper, at 200°F (93°C)	7.5
Autoignition Temperature (ASTM D-2155), °F (°C)	800 (427)
NFPA Classification 30:	1B
DOT Labels Required	Red
DOT Classification	Flammable Liquid

Table 15.12: Amyl Acetate *(2)*

Banana Oil
Amyl Acetic Ether
Isoamyl Acetate

$CH_3COOC_5H_{11}$

Amyl acetate is a colorless, flammable liquid with an odor resembling bananas or pears. Its exceptional solvent power places it among the first solvents in the nitrocellulose lacquer industry. The amyl acetates are made by the acetylation of fusel oil or synthetic amyl alcohols. Amyl acetate is miscible with oils, hydrocarbons, alcohols, ethers and esters, and will dissolve such substances as camphor, elemi, ester gums,copal ester, copals, dammar, kauri, rosin, sandarac, tannins, waxes, zanzibar and "Cumar" resins, and when it is mixed with alcohol it will dissolve some alkyd resins. It is a good solvent for cellulose esters and ethers, the solvency of which is increased when combined with ethyl alcohol. Amyl acetate is used extensively as a solvent in nitrocellulose lacquers, both for its solvency and its power to impart blush resistance, good flow, gloss and toughness. It is also used in making smokeless powder, artificial leather and pearls, airplane dopes, waterproofing compositions, varnishes, dry cleaning compounds, bronzing liquid, films, celluloid, rayon, linoleum, oilcloth, fruit flavors, soft drinks, food preparations, confectionery, perfumes, soap solvent, and in photoengraving.

	85–88% technical grade
Acidity (as acetic)	0.03% by wt, max
Blush resistance at 90°F (10% ½ sec R.S. nitrocellulose solution)	Clear 80% Relative humidity Blush 85%
Coefficient of expansion per 1°F	0.00066
per 1°C	0.00119
Color	Water-white
Dilution ratio	
Toluol	2.7
Petroleum naphtha	1.4

(continued)

Table 15.12: (continued)

85–88% technical grade

Distillation range	
Below 110°C	Not more than 15%
Below 120°C	Not more than 30%
Below 130°C	Not more than 55%
Below 140°C	Not less than 80%
Above 150°C	None
Dryness	Miscible without turbidity with 20 vols 60° Bé gasoline at 20°C
Evaporation rate at 95°F (in minutes)	
5%	1
25%	6
50%	15¼
75%	28½
90%	41¼
95%	47½
Flash point	63°F
Non-volatile matter	0.005 gm per 100 cc, max
Solubility of water in solvent at 25°C	2.4% by vol
Specific gravity at 20/20°C	0.857–0.865
Viscosity (10% ½ sec. R.S. nitrocellulose solution)	43 centipoises
Weight per gal at 20°C	7.17 lbs

(High Test 85–88%)

Acidity (as acetic)	Not more than 0.03%
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 85% Relative humidity Blush 90%
Coefficient of expansion per 1°F	0.00066
per 1°C	0.00119
Color	Water-white
Dilution ratio	
Toluol	2.5
Petroleum naphtha	1.4
Distillation range	
Below 110°C	None
Below 120°C	Not more than 10%
Below 130°C	Not more than 40%
Below 140°C	Not less than 60%
Below 150°C	None
Evaporation rate at 95°F (in minutes)	
5%	1½
25%	8¼
50%	18½
75%	30
90%	45
95%	51¾
Flash point	84°F

(High Test 85–88%)

Non-volatile matter	Not more than 0.005 gm per 100 cc
Odor	Mild
Odor residual	Non-residual
Purity	Ester content as amyl acetate 85–88%
Solubility of water in solvent at 25°C	100 cc solvent dissolves 1.8 cc water
Specific gravity at 20/20°C	0.859–0.863
Viscosity (10% ½ sec. R.S. nitrocellulose solution)	61 centipoises
Weight per gal at 20° C	7.17 lbs

90–95% grade

Acidity (as acetic)	0.035% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 85% Relative humidity Blush 90%
Coefficient of expansion	
per 1°F	0.00061
per 1°C	0.00110
Color	Water-white
Dilution ratio	
Toluol	2.6
Petroleum naphtha	1.4
Evaporation rate at 95°F (in minutes)	
5%	1¼
25%	7
50%	15½
75%	25¾
90%	35
95%	40
Flash point	79°F
Distillation range	
Below 110°C	None
Below 120°C	Not more than 10%
Below 130°C	Not more than 70%
Below 140°C	Not less than 90%
Above 150°C	None
Non-volatile matter	0.005 gram per 100 cc, max
Residue	None
Solubility in water at 25°C	2% by vol
Solubility of water in solvent at 25°C	2% by vol
Specific gravity at 20/20°C	0.868 to 0.872
Viscosity (10% ½ sec. R.S. nitrocellulose solution)	60 centipoises
Weight per gal at 20°C	7.22 lbs

Table 15.13: sec-Amyl Acetate *(2)*

$$CH_3COOC_5H_{11}$$

This medium boiling solvent is a water-white liquid made by acetylation from the secondary amyl alcohols (pentanol-2 and pentanol-3). Although its solvent power is not equal to that of amyl acetate because it has a lower tolerance for diluents, as well as a less desirable odor, it has many similar properties and it is used as a nitrocellulose and ethyl cellulose solvent.

Acidity (as acetic)	0.03% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 85% Relative humidity Blush 90%
Coefficient of Expansion	
per 1°F	0.00060
per 1°C	0.00108
Color	Water-white
Dilution ratio	
Toluol	2.1
Petroleum naphtha	1.1

(continued)

Table 15.13: (continued)

Distillation range	
Below 123°C	None
Below 126°C	Not more than 10%
Below 132°C	Not more than 60%
Below 140°C	Not less than 90%
Above 145°C	None
Evaporation rate at 95°F (in minutes)	
5%	1½
25%	7½
50%	15½
75%	24½
90%	30½
95%	33½
Flash point	89° F
Non-volatile matter	0.005 gm per 100 cc, max
Residue	None
Specific gravity at 20/20°C	0.862–0.866
Solubility of water in solvent at 25°C	0.8% by vol
Viscosity (10% ½ sec. R.S. nitrocellulose solution)	75 centipoises
Weight per gal at 20°C	7.19 lbs

Table 15.14: Pentacetate *(2)*

Pentacetate made from synthetic amyl alcohol is a mixture of five isomeric amyl acetates with some free amyl alcohol. It is soluble in methanol, ethyl ether, ethyl acetate, fixed oils, acetone, oleic acid, hot stearic acid, and aromatic and aliphatic hydrocarbons. It is soluble in hot paraffin and carnauba waxes but these congeal on cooling. It is insoluble in water. The solvent power of this mixture being similar to that of amyl acetate, pentacetate finds its most important use in the manufacture of nitrocellulose lacquers. It is also used as an extractant in the production of penicillin. It also finds use in various types of poison bait.

Some of the esters to be found in Pentacetate are:

	B.P.
$CH_3CH_2CH_2CH_2CH_2OOCCH_3$	148°C
$(CH_3)_2CHCH_2CH_2OOCCH_3$	142°C
$CH_3CH_2CH(CH_3)CH_2OOCCH_3$	142°C
$CH_3CH(OOCCH_3)CH_2CH_2CH_3$	134°C
$CH_3CH_2CH(OOCCH_3)CH_2CH_3$	132°C

Acidity (as acetic)	0.03% by wt max
Coefficient of expansion at 10 to 35°C	0.00110 per °C
Color	Water-white
Distillation range	
100%	Above 126°C
95%	Above 130°C
75%	Above 135°C
25%	Above 140°C
End point	Not above 150°C
Dilution ratio	
Toluol	2.1
Petroleum naphtha	1.3
Evaporation rate at 114.8°F	
Minutes 3.92	25%
Minutes 7.92	50%
Minutes 12.50	75%
Minutes 20.00	100%
Flash point (Open Cup)	107°F
Heat of vaporization	68.5 cal/gm
Non-volatile	0.005 gm/100 cc max
Refractive index at 20°C	1.4013
Specific gravity at 20/20°C	0.860–0.870
Solubility in water	1% by vol
Solubility of water in solvent	1.5% by vol
Viscosity at +40°C	0.683 centipoises
−40°C	3.464 centipoises
Water azeotropic mixture at 92–95°C	67% Pentacetate (approx) 33% water by vol
Water content	None
Weight per gal	7.21 lbs

Table 15.15: Methyl Amyl Acetate *(2)*

Methyl Isobutyl Carbinol Acetate $CH_3COOCH(CH_3)CH_2CH(CH_3)_2$

Methyl amyl acetate is a colorless liquid with a mild and pleasant odor. This medium boiling solvent is used in nitrocellulose lacquer fabrication producing such advantages as blush resistance, reduction of "orange peel" in the lacquer film, and no swelling of oilbase undercoats.

Acidity (as acetic)	0.02% by wt, max	Color	Water-white
Boiling range at 760 mm	Below 140°C None Above 150°C None Not more than 5% distills below 143°C Not less than 95% distills below 148°C	Dryness	Miscible with 19 vol 60° Bé gasoline at 20°C
		Purity	95% by wt, max
		Specific gravity at 20/20°C	0.855 to 0.860
		Weight per gal at 20°C	7.14 lbs

Table 15.16: 2-Ethyl Butyl Acetate *(2)*

2-Ethyl butyl acetate is a colorless liquid having a mild odor. It is a solvent for nitrocellulose, gums and resins, and is employed as a high-boiling solvent in lacquers.

Acidity (as acetic)	0.01% by wt, max	Boiling range	155°-164°C
Color	Water-white	Purity	90% min
Specific gravity	0.875 to 0.881 at $\frac{20°C}{20°C}$	Dryness	Miscible with 19 vols Bé gasoline at 20°C
		Average weight	7.33 lbs/gal (20°C)

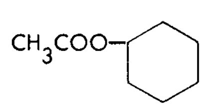
Table 15.17: 2-Ethylhexyl Acetate *(41)*

Ethylhexyl acetate is a water-white, stable liquid. It will dissolve nitrocellulose and many of the natural and synthetic resins. It is used in slow-evaporating preparations such as brushing and dipping lacquers, mist coatings, baking finishes and lacquer emulsions.

Molecular Weight ($C_{10}H_{20}O_2$)	172.26	Fire Point, °F (°C)	187 (86)
Color (Pt-Co Scale), max	15	Flammable Limits in Air, % by volume	
Weight/Vol, 20°C,		Lower, at 200°F (93°C)	0.76
lb/gal (U. S.)	7.26	Upper, at 300°F (149°C)	8.14
kg/liter	0.87	Autoignition Temperature (ASTM D-2155), °F (°C)	515 (268)
lb/gal (Imperial)	8.71	NFPA Classification 30	IIIA
Solubility, 20°C, wt %		DOT Labels Required	None
In water	0.03	DOT Classification	Nonhazardous Liquid
Water in	0.55	Color (Pt-Co Scale), ppm, max	15
Evaporation Rate (n-butyl acetate = 1)	0.03	Specific Gravity, 20°/20°C	0.870-0.875
Dilution Ratio, toluene	1.4	Acidity, as acetic acid, wt %, max	0.02
VM & P naphtha	0.9	Boiling Range, 760 mm, °C	
Refractive Index, 20°C	1.4103	Initial boiling point, min	192.0
Vapor Pressure, 20°C, mm Hg	0.4	Dry point, max	205.0
Specific Gravity, 20°/20°C	0.872	Ester Content, wt %, min	95.0
Boiling Range, 760 mm, °C		Water, wt %, max	0.2
Initial Boiling Point, min	192.0	Odor	Mild
Dry Point, max	205.0		
Freezing Point, °F (°C)	−135 (−93)		
Flash Point, Tag Closed Cup, °F (°C)	160 (71)		
Tag Open Cup, °F (°C)	175 (79)		

Table 15.18: Cyclohexyl Acetate *(2)*

Hexalin Acetate
Hexahydrophenyl Acetate
Adronol Acetate



Cyclohexyl acetate is a colorless, water-insoluble liquid with an odor resembling that of amyl acetate. It is miscible in all proportions with most of the lacquer solvents and diluents, with halogenated and hydrogenated hydrocarbons, and will completely dissolve waxed dammar and unrun congo copal. It is a good solvent for cellulose ethers and nitrocellulose and has powerful solvency for basic dyes, blown oils, raw rubber, metallic soaps, driers, shellac, bitumens, and a wide range of natural and synthetic resins and gums. It is used in spraying and brushing lacquers importing blush resistance and good flow.

(continued)

Table 15.18: (continued)

Boiling range	160–180°C
Color	Water-white
Flash point	64°C
Freezing point	−65°C
Purity	88–95% min
Residue	None
Refractive index	1.435–1.445
Specific gravity at 20°C	0.968–0.972
Water	None
Viscosity (S.U.V. at 100°F)	32

Table 15.19: Methyl Cyclohexanyl Acetate *(2)*

Sextate
Methyl Hexalin Acetate
Hexahydrocresol Acetate
Hexahydromethylphenol Acetate

Methyl cyclohexanyl acetate is a colorless high-boiling liquid having an ester-like odor. Its miscibility and solvent action are quite similar to those of cyclohexanyl acetate but it is slower acting. It is a solvent for nitrocellulose, basic dyes, rubber, bitumens, oils, fats and waxes, and for such resins as dammar, elemi, manila, mastic, rosin, ester gum, phenolic and vinyl resins. It will dissolve, in a lesser degree, shellac, kauri and cellulose acetate. It is used as a high-boiling solvent in nitrocellulose lacquers for both spraying and brushing purposes. Its solvency and slow rate of evaporation impart resistance to blushing and good working qualities and produce films that are smooth, homogeneous and glossy. Its dilution ratio with various diluents are as follows:

Xylene	2.5
Toluene	2.5
Benzene	2.0
White spirits	1.5

Acidity	4.04% (max.)
Ester content	80-90%
Boiling range	175°-190°C.
Flash point	66°-69°C.
Specific gravity	0.95

Table 15.20: Ethylene Glycol Monoacetate *(2)*

$$\begin{array}{l} CH_2OH \\ | \\ CH_2OOCCH_3 \end{array}$$

Ethylene glycol monoacetate is a colorless, odorless liquid and is structurally a primary alcohol and an ester. It is made by combining a dihydric alcohol and a monocarboxylic acid. It will mix completely with water and many of the lacquer solvents. Ethylene glycol monoacetate will dissolve cellulose esters and ethers and many of the resins.

Boiling point	181°C.
Specific gravity	1.109 (20°C.)
Flash point	102°C.

Table 15.21: Ethylene Glycol Diacetate *(2)*

$$\begin{array}{l} CH_2OOCCH_3 \\ | \\ CH_2OOCCH_3 \end{array}$$

Glycol diacetate is a colorless liquid having a faint odor resembling that of ethyl acetate. It will dissolve a wide range of cellulose esters, camphor, dammar, ester gum, elemi, mastic, rosin and sandarac. When it is mixed with active solvents its range of solubility is increased for a wide variety of cellulose esters and ethers and for natural and synthetic resins.

(continued)

Table 15.21: (continued)

Molecular Weight ($C_6H_{10}O_4$)	146.15
Color (Pt-Co Scale), max	15
Weight/Vol, 20°C,	
lb/gal (U.S.)	9.21
kg/liter	1.11
lb/gal (Imperial)	11.04
Solubility, 20°C, wt %	
In water	16.4
Water in	7.6
Evaporation Rate (n-butyl acetate = 1)	0.02
Dilution Ratio, toluene	1.4
Refractive Index, 20°C	1.4159
Vapor Pressure, 20°C, mm Hg	0.2
Specific Gravity, 20°/20°C	1.107
Boiling Range, 760 mm, °C	
Initial Boiling Point, min	187.0
Dry Point, max	193.0
Freezing Point, °F (°C)	-43 (-42)
Flash Point, Tag Closed Cup, °F (°C)	191 (88)
Cleveland Open Cup, °F (°C)	210 (99)
Fire Point, °F (°C)	210 (99)
Flammable Limits in Air, % by volume	
Lower, at 275°F (135°C)	1.6
Upper, at 310°F (154°C)	8.4
Autoignition Temperature (ASTM D-2155), °F (°C)	900 (482)
NFPA Classification 30:	IIIA
DOT Labels Required	None
DOT Classification	Nonhazardous Liquid

Table 15.22: Ethylene Glycol Monomethyl Ether Acetate *(19)*

Methyl CELLOSOLVE Acetate
ARCOSOLV EMA

Typical Properties

Formula Molecular Weight	118.14
Apparent Specific Gravity at 20/20°C	1.0055
Pounds per Gallon at 20°C	8.37
Boiling Point at 760 mm Hg, °C	145.0
Vapor Pressure at 20°C, mm Hg	2
Freezing Point, °C	-65.1
Absolute Viscosity at 20°C, cP	1.1
Solubility at 20°C, % by wt	
In Water	Complete
Water In	Complete
Flash Point, Closed Cup, °F*	121
Relative Evaporation Rate (nBuAc = 100)	31
Heat of Vaporization, Btu/lb	
At 1 Atm	147
At 300 mm Hg	156

*Determined by Tag Closed Cup, ASTM Method D56.

Table 15.23: Ethylene Glycol Monoethyl Ether Acetate *(41)*

CELLOSOLVE Acetate
Eastman EE Acetate
ARCOSOLV EEA
Glycol Ether EEA

$CH_2OC_2H_5$
|
CH_2OOCCH_3

This is a water-white liquid with a mild, characteristic odor. It is widely used as a solvent in nitrocellulose lacquers where it imparts gloss, flow, and prevents blush.

(continued)

Table 15.23: (continued)

Typical Properties

Molecular Weight ($C_6H_{12}O_3$)	132.16	Boiling Range at 760 mm, °C	
Color (Pt-Co Scale), max	15	Initial Boiling Point, min	150
Weight/Vol at 20°C,		Dry Point, max	160
lb/gal (U.S.)	8.11	Freezing Point, °F (°C)	-78 (-61)
kg/L	0.98	Flash Point, Tag Closed Cup, °F (°C)	130 (54)
lb/gal (Imperial)	9.73	Tag Open Cup, °F (°C)	139 (59)
Solubility at 20°C, wt %		Fire Point, °F (°C)	144 (62)
In water	23.8	Flammable Limits in Air, % by volume	
Water in	6.5	Lower, at 200°F (93°C)	1.24
Evaporation Rate (n-butyl acetate = 1)	0.2	Upper, at 275°F (135°C)	12.7
Dilution Ratio, toluene	2.5	Autoignition Temperature (ASTM D 2155), °F (°C)	720 (382)
VM & P naphtha	0.9	NFPA Classification 30	II
Refractive Index at 20°C	1.4030	DOT Classification	Combustible Liquid
Vapor Pressure at 20°C, mm Hg	1.7	DOT Labels Required	None
Specific Gravity at 20/20°C	0.973		

Table 15.24: Ethylene Glycol Monobutyl Ether Acetate *(41)*

Butyl CELLOSOLVE Acetate
SOLV EB Acetate
Eastman EB Acetate
Glycol Ether EB Acetate
ARCOSOLV EBA
Glycol Ether EBA

$$CH_3-\underset{\underset{O}{\|}}{C}-O-CH_2-CH_2-O-C_4H_9$$

This is a high boiling glycol ether ester solvent particularly useful as a coalescing aid for latex paint. With its limited water solubility and its general solvent properties, it is found useful in multicolor lacquers and lacquer emulsions.

Typical Properties

Molecular Weight ($C_8H_{16}O_3$)	160.21
Color (Pt-Co Scale), max	15
Evaporation Rate (n-butyl acetate = 1)	0.03
Weight/Vol, 20°C,	
lb/gal (U. S.)	7.84
kg/litre	0.94
lb/gal (Imperial)	9.42
Solubility, 20°C, wt %	
In water	1.1
Water in	1.6
Dilution Ratio, toluene	1.8
VM & P naphtha	1.2
Refractive Index, 20°C	1.4200
Vapor Pressure, 20°C, mm Hg	0.29
Specific Gravity, 20°/20°C	0.942
Boiling Range, 760 mm, °C	
Initial Boiling Point, min	186
Dry Point, max	194
Freezing Point, °F (°C)	−83 (−64)
Flash Point, Tag Closed Cup, °F (°C)	160 (71)
Tag Open Cup, °F (°C)	177 (81)
Fire Point, °F (°C)	180 (82)
Flammable Limits in Air, % by volume	
Lower, at 200°F (93°C)	0.88
Upper, at 275°F (135°C)	8.54
Autoignition Temperature (ASTM D-2155), °F (°C)	645 (340)
NFPA Classification 30	IIIA
DOT Classification	Combustible Liquid
DOT Labels Required	None

Table 15.25: Diethylene Glycol Monoethyl Ether Acetate *(41)*

SOLV DE Acetate
Eastman DE Acetate
Glycol Ether DE Acetate
ARCOSOLV DEA

$$CH_3{-}\underset{\displaystyle \| \atop \displaystyle O}{C}{-}O{-}CH_2{-}CH_2{-}O{-}CH_2{-}CH_2{-}O{-}C_2H_5$$

This is primarily used as a coalescing aid in latex points. Both its solvency and slow evaporation rate are effective in producing slow drying characteristic brushing lacquers.

Typical Properties

Molecular Weight ($C_8H_{16}O$)	176.21
Color (Pt-Co Scale), max	15
Evaporation Rate (n-butyl acetate = 1)	< 0.01
Weight/Vol, 20°C,	
lb/gal (U. S.)	8.41
kg/litre	1.01
lb/gal (Imperial)	10.09
Solubility, 20°C, wt %	
In water	Complete
Water in	Complete
Dilution Ratio, toluene	2.2
VM & P naphtha	0.6
Refractive Index, 20°C	1.4230
Vapor Pressure, 20°C, mm Hg	0.05
Specific Gravity, 20°/20°C	1.011
Boiling Range, 760 mm, °C	
Initial Boiling Point, min	214
Dry Point, max	221
Freezing Point, °F (°C)	−13 (−25)
Flash Point, Cleveland Open Cup, °F (°C)	225 (107)
Fire Point, °F (°C)	230 (110)
Flammable Limits in Air, % by volume	
Lower, at 275°F (135°C)	0.98
Upper, at 365°F (185°C)	19.4
Autoignition Temperature (ASTM D-2155), °F (°C)	680 (360)
NFPA Classification 30	IIIB
DOT Classification	Nonhazardous Liquid
DOT Labels Required	None

Table 15.26: Diethylene Glycol Monobutyl Ether Acetate *(41)*

SOLV DB Acetate
Eastman DB Acetate
ARCOSOLV DBA
Glycol Ether DBA

$$CH_3{-}\underset{\displaystyle \| \atop \displaystyle O}{C}{-}O{-}CH_2{-}CH_2{-}O{-}CH_2{-}CH_2{-}O{-}C_4H_9$$

This very high-boiling glycol ester is used primarily as a solvent in printing inks and high-bake enamels, and as a coalescing aid in latex paints. The very slow evaporation rate and the limited water solubility of this solvent are especially applicable in silk screen inks and as a component in polystyrene coatings for decals. Also it is a selective solvent in the separation of alcohols and ketones by distillation.

Molecular Weight (theoretical)	204.27
Weight/Vol, 20°C, lb/gal (U. S.)	8.16
kg/liter	0.98
lb/gal (Imperial)	9.79
Evaporation Rate (n-butyl acetate = 1)	<0.01
Dilution Ratio, toluene	1.8
VM & P naphtha	0.9
Flash Point (Cleveland open cup), °F	240
°C	116
Freezing Point, °F	−26
°C	−32
Vapor Pressure, 20°C, mm Hg	0.04
Solubility, 20°C, wt %,	
In water	6.5
Water in	3.7
Color (Pt-Co Scale), ppm, max	15
Acidity, as acetic acid, wt %, max	0.03
Boiling Range, 760 mm, °C	
Initial boiling point, min	235.0
Dry point, max	250.0
Specific Gravity, 20°/20°C	0.975-0.985
Ester Content, wt %, min	97.0
Water, wt %, max	0.2

Table 15.27: Propylene Glycol Monomethyl Ether Acetate *(41)*

ARCOSOLV PM Acetate	Eastman PM Acetate
DOWANOL PMA	Glycol Ether PM Acetate
Methyl PROPASOL Acetate	ARCOSOLV PMA

Typical Properties

Molecular Weight ($C_6H_{12}O_3$)	132.2
Color (Pt-Co Scale)	15
Evaporation Rate (n-butyl acetate = 1)	0.39
Weight/Vol at 20° C,	
lb/gal (U.S.)	8.06
kg/L	0.97
lb/gal (Imperial)	9.68
Solubility at 20° C, wt %	
In water	20
Water in	5.9
Dilution Ratio,	
Toluene	2.6
VM & P naphtha	0.8
Refractive Index at 20° C	1.40
Vapor Pressure at 20° C, mm Hg	3.7
Specific Gravity at 20°/20° C	0.97
Boiling Range at 760 mm, ° C	
Initial Boiling Point, min.	140
Dry Point, max.	150
Flash Point by Setaflash, ° C (° F)	45 (114)
Flammable Limits in Air, % by volume	
Lower at 78° C (173° F)	1.3
Upper at 139° C (283° F)	13.1
Autoignition Temperature (ASTM D 2155), ° C (° F)	354 (670)
DOT Classification	Combustible Liquid
DOT Labels Required	None

Table 15.28: Propylene Glycol Monoethyl Ether Acetate *(70)*

ARCOSOLV PEA

ACETATES	ARCO TRADENAME	CHEMICAL NAME	CHEMICAL STRUCTURE	CAS#	MOL. WT.	BOILING PT. °C 760mm	SPECIFIC GRAVITY 20/20	LBS/GAL 20°C	SETA FLASH°F	EVAPORATION RATE (n-BuAc=100)
ARCOSOLV	PMA	Propylene Glycol Methyl Ether Acetate	$CH_3OCH_2CHCH_3OOCCH_3$	108-65-6	132.2	145.8	0.969	8.03	114	34
	PEA	Propylene Glycol Ethyl Ether Acetate	$CH_3CH_2OCH_2CHCH_3OOCCH_3$	98516-30-4	146.2	158	0.941	7.83	129	19
	DPMA	Dipropylene Glycol Methyl Ether Acetate	$CH_3(OCH_2CHCH_3)_2OOCCH_3$	88917-22-0	190.2	209.3	0.976	8.18	186	<1
E-Series	EMA	Ethylene Glycol Methyl Ether Acetate	$CH_3OC_2H_4OOCCH_3$	110-49-6	118.14	145	1.006	8.37	120 TCC[2]	35
	EEA	Ethylene Glycol Ethyl Ether Acetate	$C_2H_5OC_2H_4OOCCH_3$	111-15-9	132.16	150	0.973	8.11	130 TCC[2]	20
	EBA'	Ethylene Glycol Butyl Ether Acetate	$C_4H_9OC_2H_4OOCCH_3$	112-07-2	160.21	186	0.941	7.84	160 TCC[2]	3
	DEA	Diethylene Glycol Ethyl Ether Acetate	$C_2H_5(OC_2H_4)_2OOCCH_3$	112-15-2	176.21	214	1.012	8.42	225 COC[5]	0.8
	DBA	Diethylene Glycol Butyl Ether Acetate	$C_4H_9(OC_2H_4)_2OOCCH_3$	124-17-4	204.27	235	0.980	8.16	240 COC[5]	0.2

ACETATES							HANSEN SOLUBILITY PARAMETERS						
	ARCO TRADENAME	%SOL. IN H_2O 20°C	REF. INDEX 25°C	SURF. TENSION DYNES/CM 25°C	VAPOR PRESS mmHg 20°C	Visc. cps. 25°C	CGS HANSEN D	CGS HANSEN P	CGS HANSEN H	CGS TOTAL HANSEN	HEAT OF VAPORIZ. CAL/°C	SPECIFIC HEAT Cal/g°C 25°C	HLB DAVIES
ARCOSOLV	34	18	1.400	27.4	3.8	1.1	7.5	2.3	4.2	8.9	87.0	0.42	8.3
	19	10	1.401	26.3	1.5	1.3	7.5	2.0	3.9	8.7	69.0	0.44	7.9
	<1	12	1.414	28.3	0.05	2.1	7.3	2.3	3.9	8.6	59.1	0.42	8.2
E-Series	35	100	1.4025	34.0	2	1.1	7.2	4.8	4.4	9.9	81.7		8.8
	20	24	1.4030	28.2	1.7	1.3	7.8	2.3	5.2	9.7			8.3
	3	1	1.4142	30.3	0.29	1.8	7.5	2.2	4.3	8.9			7.4
	0.8	100	1.4220	31.7	0.05	2.8	7.9	2.5	4.5	9.4			8.7
	0.2	6	1.4239	30.0	0.04	3.2	7.8	2.0	4.0	9.0			7.7

(continued)

Table 15.28: (continued)

Regulatory Information

ACETATES:	HMIS CODES HEALTH	HMIS CODES FLAMM.	HMIS CODES REACT.	PERS. PROT.	NFPA CODES HEALTH	NFPA CODES FLAMM.	NFPA CODES REACT.	1990 CAAA HAP[1]	SARA TITLE III SEC. 313[1,4]
ARCOSOLV P-Series	2	2	0	B	0	2	0	no	no
	2	2	0	X	1	2	0	no	no
	1	2	0	B	0	2	0	no	no
E-Series					1	2		yes	yes
					1	2		yes	yes
					1	2	0	yes	yes
					1	1	0	yes	yes
					1	1	0	yes	yes

Table 15.29: Dipropylene Glycol Monomethyl Ether Acetate (DPMA) *(70)*

ARCOSOLV DPMA　　Glycol Ether DPM Acetate
DOWANOL DPMA

ARCO Chemical Company Nomenclature	Chemical Name	Molecular Weight	Boiling Point °C (760 mm Hg)	Flash Point[2] °F	Specific Gravity at 25°C	Evaporation Rate BuAC = 100	Vapor Pressure at 25°C mm Hg	Lbs/Gal at 25°C
ARCOSOLV® DPM Acetate	Dipropylene Glycol Methyl Ether Acetate (DPMA)	190.2	210	186	.972	<1	0.2	8.14

ARCO Chemical Company Nomenclature	Viscosity (centistokes) at 25°C	Surface Tension dynes/cm at 25°C	Freeze Point °F	Solubility Parameter[3]	Solubility in Water ml/100 ml	Tradenames of Competitive Products: Union Carbide	Tradenames of Competitive Products: Eastman
ARCOSOLV® DPM Acetate	2.2	28.3	<−67	8.3	12.3	–	–

1. *Values should not be regarded as specifications, maxima or minima.*
2. *Flash points below 200°F by Tag Closed Cup. Flash points above 200° by Pensky-Martens Closed Cup.*
3. *For a discussion of solubility parameters, see H. Burrel,* Interchemical Review, *Vol. 14, No. 1.*

Table 15.30: Propylene-Based Glycol Ether Acetate *(23)*

DOWANOL BC-300

DOWANOL	CHEMICAL NAME	STRUCTURAL FORMULA	Molecular Weight	Boiling Pt. °C 760 mm Hg	Flash Point °F	Evap. Rate BuAc = 1.00	Specific Gravity 25/25°C
BC-300	Propylene-Based Glycol Ether Acetate		—	145.0-210.0	108[3]	0.21	0.97

Lb/Gal 25°C	Viscosity Centi-stokes 25°C	Vapor Pressure at 25°C (mm Hg)	Surface Tension (dynes/cm)	DILUTION RATIO: Toluene	DILUTION RATIO: Naphtha	SOLVENT CONSTANTS: Solubility Parameters[1]	SOLVENT CONSTANTS: Hydrogen Bonding[2]	SOLVENT CONSTANTS: Dipole Moment (Debye)	SOLVENT CONSTANTS: Solubility in Water ml/100 ml
8.09	1.28	~3.7	27.9	2.4	0.5	9.1	9.6	1.8	20.3

[1] Solubility Parameters are useful as a guide in determining the ability of a solvent or solvent mixture to dissolve resins. A discussion of solubility parameters and the basis for these values are contained in an article by H.S. Burrell in the Spring 1955 issue of *Interchemical Review.*

[2] A discussion of the hydrogen bonding parameter is contained in an article by Allen A. Orr in the August 1975 issue of *Journal of Paint Technology*, Vol. 47, No. 607, pages 45–49. This particular article was the basis of the listed values of the hydrogen bonding parameter.

PROPIONATES

CH_3CH_2COOR

The propionic esters are very similar to the acetic esters in physical and chemical properties with the difference that the former have a higher boiling point, lower evaporation rate and a lesser power of solubility. They are miscible with many of the lacquer solvents and diluents and possess a distinctive but not a disagreeable odor. The consumption of these esters for solvent purposes is relatively small compared to the highly developed acetate esters.

Table 15.31: Methyl Propionate *(2)*

$CH_3CH_2COOCH_3$

Methyl propionate has been advocated as a solvent for cellulose derivatives. When it is admixed with other propionates (such as ethyl, propyl, butyl and amyl) the mixture will dissolve cellulase ethers and esters.

Boiling point	91°C.
Specific gravity	0.937 (4°C.)

Table 15.32: Ethyl Propionate *(2)*

Propionic Ether
Propionic Ester

$CH_3CH_2COOCH_2CH_3$

Ethyl propionate is a colorless liquid with an odor resembling that of pineapples. It is a solvent for cellulose ethers and esters and for a variety of natural and synthetic resins. It is used principally as an ingredient in soft drinks and fruit syrups.

Acidity (as propionic)	0.02% by wt, max	Evaporation rate	Slower than ethyl acetate
Distillation range	90 to 100% between 80 and 120°C	Purity	85 to 90%
Color	Water-white	Residue	None
Toluene dilution ratio	2.5–3.0	Specific gravity at 15½°C	0.876–0.886
Dryness	No turbidity with 19 volumes gasoline	Weight per gal	7.35 lbs

Table 15.33: n-Butyl Propionate *(2)*

$CH_3CH_2COOC_4H_9$

n-Butyl propianate is a water-white liquid with an apple-like odor. It is miscible with most of the lacquer solvents and diluents and with oils but not miscible with water. It is a solvent for nitrocellulose and mony of the natural and synthetic resins. When an active solvent is added to it, butyl propionate will dissolve many of the cellulose esters and ethers. It It may be used as a solvent in lacquer fabrication where it imparts gloss, adhesion and prevents blushing. It is also used to replace butyl and amyl acetate when lower volatility and slower evaporation are desired.

Acidity (as propionic)	0.35% by wt, max	Evaporation rate at 95°F (in minutes)	
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 85% Relative humidity Blush 90%	5%	2½
		25%	12
		50%	24¾
		75%	41½
Distillation range	120–175°C	90%	56½
Coefficient of expansion		95%	63¾
per 1°F	0.00060	Flash point	63°F
per 1°C	0.001	Non-volatile matter	0.005 gm/100 cc, max
Color	Water-white	Purity	90–92%
Dilution ratio		Residue	None
Toluol	2.1	Solubility of water in solvent at 25°C	1.2% by vol
Petroleum naphtha	1.2		
Distillation range:		Specific gravity at 20/20°C	0.868–0.872
Below 120°C	None	Viscosity (10% ½ sec. R.S. nitrocellulose solution)	5.9 centipoises
Below 140°C	Not more than 50%		
Below 150°C	Not less than 85%	Weight per gal at 20°C	7.24 lbs
Above 160°C	None		
Dryness at 20°C	Miscible without turbidity with 20 volumes 60° Bé gasoline		

Table 15.34: Amyl Propionate *(2)*

$$CH_3CH_2COOC_5H_{11}$$

Amyl propionate is a colorless, volatile liquid with an apple-like odor. It will dissolve cumar resins, elemi, ester gum, mastic, copal, kauri, sandarac, and nitrocellulose and it is miscible with most lacquer solvents and oils. It has a slow solvent action upon cellulose ethers thus acting as a latent solvent and this latency can be overcome when acetone or ethyl alcohol is added to it. It has similar solvent properties to amyl acetate but is not as rapid and its solutions are more viscous, it has a slower rate of evaporation, and it has a more agreeable odor. It is used as a desirable high-boiling lacquer solvent imparting gloss, blush resistance and a reduction in "orange peel" effect. It is also used in flavoring and perfumery.

Acidity (as propionic)	0.030% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 90% Relative humidity Blush 95%
Coefficient of expansion	
per 1°F	0.00060
per 1°C	0.00108
Color	Water-white
Dilution ratio	
Toluol	1.4
Petroleum naphtha	0.7
Distillation range:	
At or below 110°C	None
At or below 150°C	Not more than 40%
At or below 170°C	Not less than 90%
Above 175° C	None
Non-volatile matter	Not more than 0.005 gms per 100 cc
Residue	None
Solubility of water in solvent at 25°C	0.3% by vol
Specific gravity at 20/20°C	0.869–0.873
Viscosity (10% ½ sec. R.S. nitrocellulose solution)	106 centipoises
Weight per gal at 20°C	7.25 lbs

Table 15.35: Ethyl 3-Ethoxypropionate *(19)*

Typical Properties

Molecular Weight	146.19
Boiling Point at 760 mm Hg, °C	170.1
Vapor Pressure at 20°C, mm Hg	<1
Relative Evaporation Rate (BuAc = 100)	11
Apparent Specific Gravity at 20/20°C	0.950
Solubility Parameters	
Total	9.0
Polar	4.1
Hydrogen Bonding	4.0
Solubility of Pure Material at 20°C, % by wt	
In water	1.6
Water In	1.9
Pounds per Gallon at 20°C	7.91
Flash Point, Closed Cup, °F	136
Surface Tension at 25°C, dynes/cm	27.3

BUTYRATES

Butyrates do not find extensive use in the solvent industry because of their relatively unpleasant odor and higher price.

Table 15.36: Methyl Butyrate *(2)*

$CH_3CH_2CH_2COOCH_3$

Methyl butyrate is a solvent for ethyl cellulose and when it is mixed with active solvents it will dissolve nitrocellulose.

Boiling point	102°C.
Specific gravity	0.898 (20°C.)

Table 15.37: Ethyl Butyrate *(2)*

$CH_3CH_2CH_2COOC_2H_5$

Ethyl butyrate is a nontoxic liquid having an odor suggestive of pineapples. Its solvent properties lie between those of ethyl acetate and n-butyl acetate, and when mixed with other solvents it will dissolve cellulose esters and ethers, and many of the natural and synthetic resins. It is used in flavors.

Boiling point	120°C.
Flash point	23°C.
Specific gravity	0.879 (20°C.)

Table 15.38: n-Butyl Butyrate *(2)*

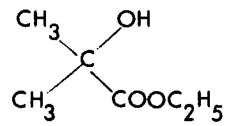
$CH_3CH_2CH_2COOC_4H_9$

Butyl butyrate is a water-white, neutral liquid with an apple-like odor. The commercial grade is composed of a mixture of the isomeric esters. It is a solvent for nitrocellulose, "Cumar" resins, dammar, ester gum, elemi, shellac, and metallic resinates.

Acidity (as butyric)	0.02% by wt, max
Boiling point	156.9° C
Distillation range	95–100% between 140–170°C
Critical temperature	338°C
Toluene dilution ratio	1.8–2.0
Dryness	No turbidity with 19 vol 60° Bé gasoline
	Complete, standing at least 19 vols gasoline without turbidity
Flash point	51°C
Purity	90–95%
Refractive index	1.4035
Residue	None
Specific gravity at 20/20°C	0.8717
Specific heat at 20°C	0.458
Surface tension at 157°C	12.0
Vapor pressure at 20°C	113 mm Hg
Viscosity at 25°C	0.84 centipoises
Weight per gal	7.25 lbs

Table 15.39: Ethyl Hydroxy-Isobutyrate *(2)*

Ethyl Oxybutyrate

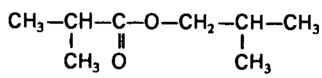


Ethyl hydroxy-isobutyrate is a water-white, stable liquid of a mild odor. It is a solvent for cellulose nitrate and acetate and when mixed with other solvents it will also dissolve cellulose ethers. Its solvent action is somewhat comparable with that of ethyl lactate, differing in the following aspects:

Its solvent action is slower and requires the presence of an active solvent to accentuate it.
Its solutions of nitrocellulose are more viscous.
Its tolerance for hydrocarbons is about the same as far as it concerns nitrocellulose and is lower in the presence of acetyl cellulose.
Its volatility is higher.

Ester content	96-100%
Boiling range	142°-146°C.
Specific gravity	0.978-0.986 (20°C.)

Table 15.40: Isobutyl Isobutyrate *(41)*



Isobutyl isobutyrate is a slow evaporating solvent with blush resistance, good flow and leveling which are favorable properties in formulating cellulose nitrate. Its solvent activity is equivalent to methyl amyl acetate and is therefore used as a direct substitute in many formulations.

Molecular Weight ($C_8H_{16}O_2$)	144.22	Boiling Range, 760 mm, °C	
Color (Pt-Co Scale), max	15	Initial Boiling Point, min	144
Weight/Vol, 20°C,		Dry Point, max	151
lb/gal (U.S.)	7.13	Freezing Point, °F (°C)	-112 (-80)
kg/liter	0.86	Flash Point, Tag Closed Cup, °F (°C)	101 (38)
lb/gal (Imperial)	8.56	Tag Open Cup, °F (°C)	111 (44)
Solubility, 20°C, wt %		Fire Point, °F (°C)	115 (46)
In water	<0.1	Flammable Limits in Air, % by volume	
Water in	<0.2	Lower, at 200°F (93°C)	0.96
Evaporation Rate (n-butyl acetate = 1)	0.4	Upper, at 200°F (93°C)	7.59
Dilution Ratio, toluene	1.5	Autoignition Temperature (ASTM D-2155), °F (°C)	810 (432)
VM & P naphtha	0.8	NFPA Classification 30:	II
Refractive Index, 20°C	1.3913	DOT Labels Required	None
Vapor Pressure, 20°C, mm Hg	3.2	DOT Classification	Nonhazardous Liquid
Specific Gravity, 20°/20°C	0.855		

Table 15.41: 2,2,4-Trimethylpentanediol-1,3-Monoisobutyrate *(41)*

	Evaporation Rate n-BuOAc = 1	Lb/ Gal @ 20°C	Color Pt-Co Max	Specific Gravity @ 20°/20°C	Acidity, as Acetic Acid Max Wt %	Boiling Range °C	Freezing Point °C	Flash Point COC °C (°F)	Fire Point °C (°F)
TEXANOL® Ester Alcohol (2,2,4-Trimethyl-1,3-pentanediol Monoisobutyrate) $C_{12}H_{24}O_3$	0.002	7.90	20	0.950	0.2 (isobutyric)	244-247	-50	120 (248)	132 (270)

COMPARATIVE DATA

Table 15.42: ARCOSOLV PM Acetate and ARCOSOLV PE Acetate *(70)*

ARCOSOLV PMA is a colorless, combustible liquid with low toxicity. It has a characteristic ester odor and is soluble in water to the extent of 18% at 20°C. It has excellent solvency for a variety of substances including acrylic, nitrocellulose and urethane coating resins. ARCOSOLV PMA is a substitute for ethylene glycol (E-series) ether acetates, particularly EEA and EMA.

Product Identification

Chemical Name.........1-Methoxy-2-Propanol Acetate
Chemical Family......Propylene Glycol Ether Acetate
Other Names ....Methoxy Propanol Acetate
................Propylene Glycol Methyl Ether Acetate
................................1- Methoxy Propanol Acetate
Chemical Formula ....$C_6H_{12}O_3$

Product Specifications[1]

Property	Specifications	Test Method
Specific Gravity @ 25/25°C	0.963 – 0.966	ASTM D-891
Distillation @ 760mm Hg		ASTM D-1078
IBP, min.	140°C	
DP, max.	150°C	
Acidity, wt. % as acetic acid, max.	0.02	ASTM D-1613
Water, wt. %, max.	0.05	ASTM E-203
Color, APHA, max.	10	ASTM E-1209
GC Purity, wt. %, min.	99.0	ACC 8314

[1] 50-75 ppm BHT is added to control peroxides.

Typical Properties

- Autoignition temperature (°F) 522
- Density (pounds per gallon at 25°C) 8.0
- Evaporation Rate (BuAc = 100)..........................34
- Flammability Limits (Lower/Upper Vol. %) 1.5/10
- Flash Point (Tag Closed Cup) °C (°F)........47 (116)
- Solubility by weight in water at 20°C 18
- Solubility by weight of water in at 20°C 6
- Solubility Parameter (Total Hansen) 9.2
- Surface Tension (Dynes/cm) @ 25°C (77°F) 27
- Refractive Index @ 25°C (77°F)........................1.40
- Viscosity (centistokes) @ 25°C (77°F) 1.1
- Vapor Pressure @ 25°C (mm Hg)......................3.8

(continued)

Table 15.42: (continued)

ARCOSOLV PEA is a colorless, liquid with a low order of toxicity. It has a mild, ether-like odor. It is slightly soluble in water but miscible with a number of organic solvents and has good solvency for a number of substances.

Product Identification

CHEMICAL NAME
- Ethoxy Propanol Acetate

OTHER NAMES
- Propylene Glycol Monoethyl Ether Acetate

CHEMICAL FAMILY
- Propylene Glycol Ether Acetate

CHEMICAL FORMULA
- $C_7H_{14}O_3$

Product Specifications

Property	Specifications	Test Method
Specific Gravity @ 20/20°C	0.942 – 0.948[1]	ASTM D-891
Distillation @ 760mm Hg		
IBP, Initial Boiling Point, min.	148°C	ASTM D-1078
DP, Dry Point, max.	168°C	
Acidity, wt. % as acetic acid, max.	0.02	ASTM D-1613
Water, wt. %, max.	0.05	ASTM E-203
Color, APHA, max.	15	ASTM D-1209

[1] Equivalent specific gravity range at 25°/25°C is 0.934 – 0.940

Typical Properties

Boiling Point °C (°F)	158 (316)
Density (pounds per gallon at 20°C)	7.5
Evaporation Rate (nBuAc = 1)	0.19
Flash Point (SETA) °C (°F)	54 (129)
Formula Molecular Weight	146
Refractive Index @ 25°C	1.40
Solubility by weight in water	10%
Viscosity (centistokes) @ 20°C (68°F)	1.3
Vapor Pressure @ 20°C (68°F) (mm Hg)	1.5

Table 15.43: Ashland Ester Solvents *(69)*

PRODUCT	LB./GAL. 20° C	SP. GR. 20°/20° C	BOILING RANGE °C	BOILING RANGE °F	FL. PT. °F TCC	EVAP. RATE[1]
Ethyl Acetate 99%	7.51	0.902	75.5-78.0	168-172	24	4.1
Isopropyl Acetate 99%	7.27	0.872	85-90	185-194	42	3.0
n-Propyl Acetate	7.39	0.888	99-103	210-217	55	2.3
Ethyl Propionate	7.42	0.892	99-	210-	61	3.1
Isobutyl Acetate	7.25	0.870	112-119	234-246	63	1.6
n-Butyl Acetate 99%	7.35	0.882	120-128	248-262	81	1.0
Glycol Ether PM Acetate	8.06	0.970	140-150	284-302	114	0.4
Amyl Acetate (primary)	7.29	0.876	142-152	288-306	101	0.49
Isobutyl Isobutyrate	7.13	0.855	144-151	291-304	104	0.45
n-Butyl Propionate	7.29	0.876	145-	292-	97	0.45
Ester Solvent EEP	7.91	0.950	165-172	329-342	136	0.12
n-Pentyl Propionate	7.27	0.872	168-	334-	138	0.18
Glycol Ether EB Acetate	7.84	0.942	186-194	367-381	165	0.03
2-Ethylhexyl Acetate	7.26	0.872	192-205	378-401	160	0.03
Glycol Ether DPM Acetate	8.12	0.976	193-205	379-401	186	<0.01
Dibasic Ester	9.10	1.092	196-212	385-414	212[a]	<0.01
Glycol Ether DE Acetate	8.41	1.011	214-221	417-430	225[a]	<0.01
Glycol Ether DB Acetate	8.16	0.980	235-250	455-482	221[a]	<0.01

[1] n-Butyl Acetate = 1 [a] PMCC

Table 15.44: Chemcentral Esters *(67)*

ESTERS	CAS	Mole Weight	% Purity Comm. Prod.	Spec. Grav. @ 20/20°C	Lbs./Gal. @ 20°C	Coeff. of Expan. Per °C	ΔSp. Gr. Per °C	Refractive Index @ 20°C	Distillation Range @ 760 mm Hg °C	Distillation Range @ 760 mm Hg °F	Vapor Press. @ 20°C mm Hg
AMYL ACETATE (Primary)	628-63-7	130.18	95	0.876	7.29	0.00115	.00080	1.4018	104-150	284-302	4.0
iso-BUTYL ACETATE	110-19-0	116.16	90	0.868	7.26	0.00137	.00098	1.3892	112-119	233-246	12.5
n-BUTYL ACETATE	123-86-4	116.16	98	0.882	7.35	0.00113	.00082	1.3947	120-128	248-262	7.8
GLYCOL ETHER DB ACETATE	124-17-4	204.26	95	0.980	8.16	0.00097	.00072	1.4265	235-259	455-482	< 0.001
GLYCOL ETHER EB ACETATE	**112-07-2**	**160.22**	**99**	**0.942**	**7.84**	**0.00104**	**.00076**	**1.4200**	**188-192**	**370-378**	**0.29**
GLYCOL ETHER DE ACETATE	112-15-2	176.21	97	1.011	8.41	0.00101	.00078	1.4230	214-221	417-430	0.05
GLYCOL ETHER EE ACETATE	111-15-9	132.16	95	0.974	8.11	0.00112	.00086	1.4058	145-166	293-331	1.7
GLYCOL ETHER EM ACETATE	110-49-6	146	99	1.006	8.37	0.00109	.00084	1.4025	140-147	284-297	2.0
GLYCOL ETHER PM ACETATE	108-65-6	132.16	99	0.969	8.07			1.400	140-150	284-302	3.7
ETHYL ACETATE (85-88%)	**141-78-6**	**88.11**	**85-88**	**0.886**	**7.38**	**0.00139**	**.00102**	**1.3698**	**71-79**	**160-174**	**88.0**
ETHYL ACETATE (99%)	141-78-6	88.11	99	0.902	7.51	0.00139	.00104	1.3710	76-77.5	169-172	76.0
ETHYL 3 ETHOXY PROPINATE (EEP)	763-69-9	146.19	99	0.944	7.84				163-166	320-330	1.11
iso-PROPYL ACETATE	108-21-4	102.14	99	0.872	7.26	0.00115	.00094	1.3779	85-90	185-194	47.5
n-PROPYL ACETATE	109-60-4	102.14	96	0.886	7.39	0.0013	.00090		99-103	210-217	23.0
ISOBUTYL ISOBUTYRATE	**97-85-8**	**144.21**	**99**	**0.855**	**7.13**				**144-151**	**291-304**	**3.2**
DIBASIC ESTER (DBE)		160.0	99	1.086	9.0				196-225	385-437	

ESTERS	Evap. Rate vs. B. Acet. = 1	Solubility % by Wt. @ 20°C In H_2O	Solubility % by Wt. @ 20°C Of H_2O	Dilution Ratio Toluol	Dilution Ratio Lactol	Bl. Res. % Rel. Hum. @ 80°F	V. 8% NC @ 25°C CPS	Freeze Point °C	Flash Point T.C.C. °F	Explosive Limits % by Vol. in Air Lower	Explosive Limits % by Vol. in Air Upper	Solubility Parameter
AMYL ACETATE (Primary)	0.4	0.2	0.9	2.3	1.3	92	41	-100	106	1.1	7.5	8.5
iso-BUTYL ACETATE	1.45	0.75	1.64	2.7	1.1	80	35	-97.1	69	2.4	10.5	8.4
n-BUTYL ACETATE	1.0	0.7	1.6	2.7	1.2	83	33	-73.5	76	1.7	7.6	8.7
GLYCOL ETHER DB ACETATE	< 0.01	6.5	3.7	1.8	0.9	96	201	-32.2	240[*]	0.8	5.0	8.5
GLYCOL ETHER EB ACETATE	**0.03**	**1.1**	**1.6**	**1.8**	**1.2**	**96**	**92**	**-63.5**	**160**			**8.5**
GLYCOL ETHER DE ACETATE	< 0.01	∞	∞	2.2	0.6	92	158	25	230[*]	1.0	6.9	8.5
GLYCOL ETHER EE ACETATE	0.2	23.8	6.5	2.5	0.9	94	65	-61.7	130	1.7		8.7
GLYCOL ETHER EM ACETATE	0.2	∞	∞	2.3	0.6	80	63	-65.1	120			9.2
GLYCOL ETHER PM ACETATE	0.39	- 20	5.9	2.6	0.8	92	65		114[a]	1.3	13.1	8.8
ETHYL ACETATE (85-88%)	**4.2**	**7.4**	**3.1**	**3.3**	**1.2**	**38**	**23**	**< -83.6**	**26**	**2.05**	**11.0**	**9.1**
ETHYL ACETATE (99%)	4.1	7.4	3.3	3.1	1.1	39	23	-83.6	24	2.2	11.0	9.1
ETHYL 3 ETHOXY PROPINATE (EEP)	0.12	2.9		1.8			52		136[a]	1.05		9.1
iso-PROPYL ACETATE	3.1	2.9	1.8	3.0	1.2	69	25	-69	35	1.8	8.0	8.6
n-PROPYL ACETATE	2.3	2.3	2.6	3.2	1.5	65	25	-95	55	2.0	8.0	8.8
ISOBUTYL ISOBUTYRATE	**0.43**	**< 0.1**	**< 0.2**	**1.5**	**0.8**	**92**	**56**	**-81**	**97[a]**			**8.0**
DIBASIC ESTER (DBE)								20	212			

[*] Tag Open Cup [a] Seta Closed Cup

Table 15.45: CPS Chemical Esters *(15)*

SALES SPECIFICATIONS:

	Butyl Lactate	Ethyl Lactate*
Purity, % ester	95.0 minimum	98.0 minimum
Specific Gravity, 20/20 °C	0.970 to 0.990	1.032 to 1.035
Acid value	0.5 maximum	0.5 maximum
Water, wt. %	0.2 maximum	0.3 maximum
Color, APHA	25 maximum	25 maximum

*Electronic grade also available

PHYSICAL PROPERTIES:

	Butyl Lactate	Ethyl Lactate
Flash point, °C	76	48
Freezing point, °C	−46	−25
Boiling point, °C @ 760 mm Hg	188	154
Vapor pressure mm Hg @ 20°C	0.4	2
Vapor density (air = 1)	5.04	1.03
Relative evaporation rate (butyl acetate = 1)	0.044	0.29
Molecular weight	146.2	118.1
Pounds per gallon	8.15	8.59
Odor	mild	mild
Appearance	water white liquid	water white liquid

Table 15.46: Eastman Glycol Ether Esters *(41)*

NOMENCLATURE OF GLYCOL ETHERS AND GLYCOL ETHER ESTERS

GLYCOL ETHERS

Company Name	Ethylene Glycol Propyl Ether	Ethylene Glycol Butyl Ether	Ethylene Glycol 2-Ethylhexyl Ether	Diethylene Glycol Methyl Ether	Diethylene Glycol Ethyl Ether	Diethylene Glycol Propyl Ether	Diethylene Glycol Butyl Ether	Propylene Glycol Methyl Ether
Eastman	*Eastman* EP	*Eastman* EB	*Eastman* EEH	*Eastman* DM	*Eastman* DE	*Eastman* DP	*Eastman* DB	*Eastman* PM
Union Carbide	Propyl *Cellosolve*	Butyl *Cellosolve*	—	Methyl *Carbitol*	*Carbitol* (low gravity)	Propyl *Carbitol*	Butyl *Carbitol*	Methyl *Propasol*
Dow	—	*Dowanol* EB	—	*Dowanol* DM	*Dowanol* DE	—	*Dowanol* DB	*Dowanol* PM
Shell	—	Butyl *Oxitol*	—	—	—	—	Butyl *Dioxitol*	—
Occidental	—	EB	—	—	DE	—	DB	—
Arco	—	—	—	—	—	—		*Arcosolv* PM

GLYCOL ETHER ESTERS

Company Name	Ethylene Glycol Butyl Ether Acetate	Diethylene Glycol Ethyl Ether Acetate	Diethylene Glycol Butyl Ether Acetate	Propylene Glycol Methyl Ether Acetate
Eastman	*Eastman* EB acetate	*Eastman* DE acetate	*Eastman* DB acetate	*Eastman* PM acetate
Union Carbide	Butyl *Cellosolve* acetate	—	Butyl *Carbitol* acetate	Methyl *Propasol* acetate
Arco	—	—	—	*Arcosolve* PM acetate
Dow	—	—	—	*Dowanol* PM acetate
Occidental	EB acetate	—	DB acetate	PM acetate

Table 15.47: Hoechst Celanese Esters *(42)*

Ethyl Acetate

(Acetic Acid, Ethyl Ester, Ethyl Acetic Ester, Ethyl Ethanolate, Acetidin)

Physical Properties

Autoignition Temperature, °C	426.7
Boiling Point at 760 mm Hg, °C	77
Boiling Point at 760 mm Hg, °F	171
Coefficient of Thermal Expansion per °C (at 20°C)	0.00141
Critical Pressure, atmospheres (est)	37.8
Critical Temperature, °C (est)	250
Evaporation Rate (BuAc = 1)	4.5
Flammable Limits	
(lower limit, vol %)	2.0
(upper limti, vol %)	11.4
Flash Point, Tag Open Cup, °F	56
Tag Closed Cup, °F	24
Freezing Point, °C	-83
Heat of Combustion, kcal/mole (liquid, 25°C)	534.3
Heat of Formation, kcal/mole(liquid, 25°C)	-115.2
Heat of Fusion, cal/gm	28.43
Heat of Vaporization, btu/lb at normal boiling point	158
Molecular Weight	88.11
Refractive Index n_D^{20}	1.3719
Solubility at 20°C, wt % in water	8.7
wt % water in	3.3
Specific Gravity, 20/20°C	0.9019
Specific Heat of Liquid, cal/gm/°C at 20°C	0.459
Surface Tension in Air at 20°C dynes/cm	23.7
Vapor Density (air = 1)	3.0
Vapor Pressure, mm Hg, 20°C	73
Viscosity at 20°C, centipoise	0.46
Weight, pounds per gallon at 20°C	7.51

Isopropyl Acetate

(Acetic Acid, Isopropyl Ester)

Physical Properties

Autoignition Temperature, °C	460
Critical Properties:	
Temperature, °C	257.85
Pressure, atm	35.7
Volume, cm^3/mol	312
Compressibility Factor (Z_c)	0.255
Density:	
Liquid (20°C)	0.8718
Vapor (air = 1.0)	3.5
Explosive Limits (25°C), vol %	
Lower (LEL)	1.76
Upper (UEL)	7.20
Flash Point (TCC), °C	22
Latent Heat of Vaporization (25°C), kcal/mol	8.89
Liquid Specific Heat (25°C), cal/g°C	0.460
Liquid Viscosity (20°C), centipose	0.60
Melting Point, °C	-73.4
Molecular Weight	102.134
Normal Boiling Point, (n-bp), °C	88.6
Refractive Index, (n_d) at 20°C	1.3791
Standard Net Heat of Combustion, kcal/mol	-632.9 (gas)
Surface Tension (20°C), dyne/cm	22.3
Vapor Pressure (20°C), mm Hg	47

(continued)

Table 15.47: (continued)

n-Propyl Acetate

(Acetic Acid, Propyl Ester, Normal Propyl Acetate)

Physical Properties

Autoignition Temperature, °C	450.0
Boiling Point at 760 mm Hg, °C	101.6
Boiling Point at 760 mm Hg, °F	214.9
Evaporation Rate (BuAc = 1)	2.2
Flammable Limits (lower limit, vol %)	2.0
(upper limit, vol %)	8.0
Flash Point, Tag Open Cup, °F	70
Tag Closed Cup, °F	55
Freezing Point, °C	-92.5
Heat of Vaporization, btu/lb at normal boiling point	145
Molecular Weight	102.13
Solubility at 20°C, wt % in water	2.3
Specific Gravity, 20/20°C	0.8870
Specific Heat of Liquid, cal/gm/°C at 20°	0.459
Vapor Density (air = 1)	3.5
Vapor Pressure, 20°C, mm Hg	25
Viscosity at 20°C, centipoise	0.59
Weight, pounds per gallon at 20°C	7.39

Isobutyl Acetate

(Acetic Acid, Isobutyl Ester, 2-Methyl-1-Propyl Acetate, B-Methylpropyl Ethanoate)

Physical Properties

Boiling Point at 760 mm Hg, °C	118
Boiling Point at 760 mm Hg, °F	244
Coefficient of Thermal Expansion per °C at 55°C	1.26×10^{-3}
Distillation Range, °C	114.0-119.0
Evaporation Rate (BuAc = 1)	1.6
Flammable Limits (lower limit, vol %)	2.4
(upper limit, vol %)	10.5
Flash Point, Tag Open Cup, °F	83
Tag Closed Cup, °F	64
Freezing Point, °C	-99
Heat of Vaporization, k joules/mol at normal boiling point	36.7
Molecular Weight	116.16
Refractive Index, n_D^{20}	1.3900
Solubility at 20°C, wt % in water	0.63
Specific Gravity, 20/20°C	0.8724
Specific Heat of Liquid, cal/gm/°C at 20°C	0.459
Vapor Density (air = 1)	4.0
Vapor Pressure at 20°C, mm Hg	13.0
Viscosity, 20°C, centipoise	0.70
Weight, pounds per gallon at 20°C	7.26

Table 15.47: (continued)

n-Butyl Acetate
(Acetic Acid, Butyl Ester, Butyl Ethanoate, Normal Butyl Acetate)

Physical Properties

Boiling Point (760 mm Hg):	126.5°C (259.7°F)
Coefficient of Thermal Expansion per °C (at 20°C):	1.13×10^{-3}
Critical Pressure:	31.7 atm
Critical Temperature:	306.2 °C
Distillation Range:	120-128°C
Evaporation Rate (BuAc = 1):	1.0
Flammability Limits in Air (% by vol):	
Upper:	7.6
Lower:	1.7
Flash Point:	
Tag Open Cup:	93°F
Tag Closed Cup:	76°F
Freezing Point:	-73.5°C
Heat of Combustion (liquid, 25°C):	-847 kcal/mole
Heat of Formation (liquid, 25°C):	-5.17 kcal/mole
Heat of Vaporization (at normal boiling point):	139 btu/lb
Molecular Weight:	116.16
Refractive Index n_D^{20}:	1.3947
Solubility at 20°C, wt%, in water:	0.68
water in:	1.175
Specific Gravity (20/20°C):	0.8820
Specific Heat of Liquid (at 20°C):	0.503 cal/gm/°C
Surface Tension (in Air at 20°C):	24.0 dynes/cm
Vapor Density (Air = 1):	4.0
Vapor Pressure (20°C):	18.4 mm Hg
Viscosity (at 20°C, centipoise):	0.74
Weight (pound per gallon at 20°C):	7.35

Methyl Formate - 97.5%
(Formic Acid, Methyl Ester)

Physical Properties

Autoignition Temperature, °C	449.0
Boiling Point at 760 mm Hg, °C	32.1
Boiling Point at 760 mm Hg, °F	89.8
Critcal Pressure, atmospheres	59.25
Critical Temperature, °C	214
Evaporation Rate (Ether = 1)	1.6
Flammable Limits	
(lower limit, vol %)	5.0[1]
(upper limit, vol %)	23.0
Flash Point, Tag Open Cup, °F	-2
Tag Closed Cup, °F	-26
Freezing Point, °C	-100.2
Heat of Vaporization, btu/lb at normal boiling point	202.3
Molecular Weight	60.05
Refractive Index, n_D^{20}	1.3434
Solubility at 20°C, wt % in water	33.0
Specific Gravity, 20/20°C	0.980
Specific Heat of Liquid, btu/lb/°F at 68°F	0.493
Surface Tension in air at 25°C, dynes/cm	24.62
Vapor Density (air = 1)	2.07
Vapor Pressure, 20°C, mm Hg	476.4
Viscosity at 25°C, centipoise	0.355
Weight, pounds per gallon at 20°C (68°F)	8.17

Table 15.48: Mobil Oil Esters *(64)*

Typical Characteristics	**N-Butyl Acetate**	**Cyclohexyl Acetate**	**Ethyl Acetate**	**EGMEEA**
Density kg/l at 15°C	0.887	0.973	0.905	0.975
Distillation °C, IBP	124.0	173	76.6	156
DP	126.7	179	77.4	165
Color, APHA	5	5	10	10
Flash Point °C (TCC)	23	58	-1	58
Water Content % Wt.	0.1	0.09	0.1	—
Acidity as Acetic, ppm	70	140	50	100
Properties of Pure Material				
Molecular Wt.	116.16	142.19	88.10	132.09
Coefficient of Cubical Expansion/°C	0.00121	0.00095	0.00139	0.00111
Density Correction/°C	0.00104	0.00090	0.00123	0.00106
Solubility of Water in, at 20°C, % w/w	1.37	0.80	3.0	6.5
Solubility in Water, at 20°C, % w/w	1.0	0.33	7.9	23
Viscosity at 20°C, cP	0.69	2.0	0.45	1.21
Refractive Index at 20°C	1.3951	1.441	1.3725	1.4058
Specific Heat at 20°C, kJ/kg/°C	1.92	1.72	2.00	2.07
Latent Heat of Evaporation, kJ/kg	310	313	367	339
Vapor Pressure at 20°C, mm Hg	10	1.0	73	1.2
Explosive Range, % vol in air.	1.7 – 15	1.0 – ?	2.2 – 11.0	1.7 – 10.1
Sat. Vapor Explosive in range, °C	23 – 70	—	– 7 – + 33	—
Autoignition Temperature, °C	425	330	426	379

Table 15.49: Union Carbide Esters *(19)*

	MOLECULAR WEIGHT	BOILING POINT at 760 mm Hg, °C	VAPOR PRESSURE at 20°C, mm Hg	RELATIVE EVAPORATION RATE (BuAc = 100)	APPARENT SPECIFIC GRAVITY at 20/20°C	SOLUBILITY PARAMETERS Total	Polar	Hydrogen Bonding	SOLUBILITY of Pure Material at 20°C, % by weight In Water	Water In	POUNDS PER GALLON at 20°C	FLASH POINT, Closed Cup, °F	SURFACE TENSION at 25°C, dynes/cm	SURFACE TENSION at 25°C of 20% Solution in Water, dynes/cm
ESTERS														
Ethyl Acetate (99.5%)	88.11	77.2	76	747	0.902	8.91	4.20	4.35	8.7	3.3	7.51	30	23.7	24.5 (a)
CELLOSOLVE Acetate	132.16	156.3	2	20	0.975	9.35	4.41	4.33	22.9	6.5	8.10	126	28.0	33.5
Methyl PROPASOL Acetate	132.16	145.7	3	34	0.969	9.10	4.50	3.86	18.5	5.6	8.06	116	28.2	—
Ester EEP	146.19	170.1	<1	11	0.950	9.0	4.1	4.0	1.6	1.9	7.91	136	27.3	—
Butyl CELLOSOLVE Acetate	160.21	192.3	<1	3	0.942	8.91	3.92	3.83	1.5	1.7	7.84	165	27.4	41.0 (b)
Butyl CARBITOL Acetate	204.27	246.7	<1	<1	0.980	9.05	3.97	4.25	6.5	3.7	8.16	221	30.0	39.2 (c)
Filmer IBT	216.30	169.7	<1	<1	0.95	8.5	—	—	<1	0.9	7.91	248	—	—

(a) 5 percent aqueous solution. (b) 1 percent aqueous solution. (c) 2 percent aqueous solution.

Resin Solubilities

Solvent	Cellulose Acetate, 41% Acetyl	Cellulose Acetate Butyrate, 17% Butyrl	Cellulose Acetate Butyrate, 37% Butyrl	Ethyl Cellulose, 47-49% Ethoxyl	Polystyrene	Poly(methyl Methacrylate)	Vinyl Resins: VYHH Vinyl Chloride/Vinyl Acetate Copolymer	Vinyl Resins: AYAF Polyvinyl Acetate	Vinyl Resins: XYHL Polyvinyl Butyrl
Butyl CARBITOL® Solvent	I	I	G	S*	I	I	PS	S	S
Butyl CELLOSOLVE® Solvent	I	I	I	S	I	I	I	PS	S
Butyl CELLOSOLVE Acetate	I	I	S	S	S	I	Sl.S	S	I
Butyl PROPASOL® Solvent	I	I	I	S-G	I	I	I	SW	S-G
CARBITOL Solvent PM-600	I	SW	PS	PS	I	I	I	PS	S
CELLOSOLVE Acetate	Sl.S	PS	S	S	S	S	S	S	G
CELLOSOLVE Solvent	I	I	S	S	I	I	I	S	S
Methyl CARBITOL Solvent	S-G	SW	S	PS	I	I	I	S	S
Methyl CELLOSOLVE Solvent	S	I	S	S	I	S	PS	S	S
Methyl CELLOSOLVE Acetate	S	S	S	S	S	S	S	S	G
Methyl PROPASOL Acetate	I	SW	S	PS	S	S	S	S	SW
Methyl PROPASOL Solvent	I	I	S	PS	I	S	I	S	PS
Propyl CARBITOL Solvent	I	I	G	S	I	I	PS	S	S
Propyl CELLOSOLVE Solvent	I	I	S	S	I	I	I	S	S
Propyl PROPASOL Solvent	I	I	I	S-G*	I	I	I	Sl.S	S-G
UCAR® Ester EEP	—	S	—	S	PS	PS	S	—	—

Concentration = 0.5 g resin to 4.5 ml of solvent
* = 0.5 g resin to 9.5 ml solvent
S = Soluble
I = Insoluble
G = Gel
SW = Swelling
Sl.S = Slightly soluble
PS = Partly soluble
S-G = Soluble, tendency to gel
PS-G = Partly soluble, tendency to gel
Sl.S-G = Slightly soluble, tendency to gel

(continued)

Table 15.49: (continued)

Coating Performance Properties

Solvent	Solubility Parameters: Total	Polar	Hydrogen Bonding	Blush Resistance	Dilution Ratios: Toluene	Naphtha	Xylene	Relative Evaporation Rate (nBuAc = 100)	Surface Tension at 25°C, dynes/cm: Solvent	20% Solution in Water(a)
Butyl CARBITOL® Solvent	9.79	3.94	6.16	—	3.9	1.9	4.2	< 1	31.0	33.2
Butyl CELLOSOLVE® Acetate	8.91	3.92	3.83	96 +	1.8	1.2	—	3	27.4	41.0(b)
Butyl CELLOSOLVE Solvent	9.87	3.88	6.35	96 +	3.5	2.3	3.2	6	28.6	28.9
Butyl PROPASOL® Solvent	9.31	3.67	5.63	96 +	1.9	0.9	—	8	27.4	32.3(c)
CARBITOL Solvent, Low Gravity	10.34	4.35	6.89	78	4.7	0.5	—	< 1	35.2	49.6
CARBITOL Solvent PM 600	10.3	—	—	76	1.9	Imm.	1.2	< 1		
CELLOSOLVE Acetate	9.35	4.41	4.33	94	2.5	0.9	2.3	20	28.0	33.5
CELLOSOLVE Solvent	10.71	4.43	7.42	59	4.9	1.1	4.3	32	29.4	47.1
Hexyl CARBITOL Solvent	9.70	3.08	5.84	—	2.9	1.8	—	< 1	29.6	—
Hexyl CELLOSOLVE Solvent	9.63	3.53	5.90	96 +	2.4	1.5	—	1	30.3	28.5
Methyl CARBITOL Solvent	11.15	4.70	7.70	76	2.3	Imm.	1.0	< 1	35.9	49.6
Methyl CELLOSOLVE Acetate	9.9	—	—	80	2.3	0.6	1.9	31	—	—
Methyl CELLOSOLVE Solvent	11.7	—	—	42	4.0	Imm.	2.9	47		
Methyl PROPASOL Acetate	9.10	4.50	3.86	—	2.5	0.8	—	34	28.2	—
Methyl PROPASOL Solvent	10.42	4.48	6.98	—	5.2	0.9	—	60	28.3	46.8
Propyl CARBITOL Solvent	9.99	4.11	6.46	—	—	—	—	< 1	—	—
Propyl CELLOSOLVE Solvent	10.16	4.10	6.77	69	4.0	2.0	—	22	26.7	—
Propyl PROPASOL Solvent	9.55	3.89	5.89	—	—	1.1	—	22	27.0	30.4
UCAR® DPM Solvent	9.4	—	13.3	—	4.2	0.8	—	3	28.8	—
UCAR Ester EEP	9.0	4.1	4.0	—	1.4	0.7	—	11	27.3	—

(a) All solutions are percent by volume
(b) 1 percent aqueous solution
(c) 5 percent aqueous solution

Constant Boiling Azeotropic Mixtures of Glycol Ether Esters with Water

GLYCOL ETHER ESTER MIXTURES

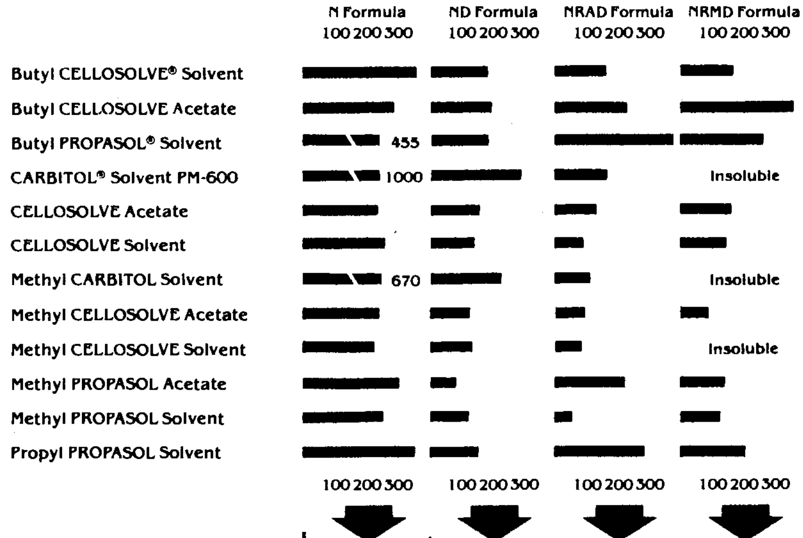
Solvent	Components: Specific Gravity at 20/20°C	Boiling Point, °C at 760 mm Hg	Azeotrope: Boiling Point, °C at 760 mm Hg	Composition, % by Wt. at 20°C: In Azeotrope	In Upper Layer	In Lower Layer	Relative Volume of Layers(a) at 20°C	Sp. Gr. 20/20°C of Azeotrope Layer(a)
Butyl CELLOSOLVE Acetate	0.9442	191.5	98.8	28.1	98.4	1.1	U 71.0	U 0.941
Water	1.0000	100.0		71.9	1.6	98.9	L 29.0	L 0.999
CELLOSOLVE Acetate	0.9748	156.4	97.5	45.5	93.3	24.5	U 31.2	U 0.972
Water	1.0000	100.0		54.5	6.7	75.5	L 68.8	L 1.011
Methyl CELLOSOLVE Acetate	1.0067	145.5	97.1	48.2	—	—	—	1.03
Water	1.0000	100.0		51.8	—	—	—	
UCAR® Ester EEP	0.9496	170.1	97	38.6	97.2	5.3	U 38	U 0.94
Water	1.0000	100.0		61.4	2.8	94.7	L 62	L 0.99

(a) U = Upper; L = Lower

(continued)

Table 15.49: (continued)

Relative Viscosities of Lacquers at 25°C



Composition of Formulas	N Formula	ND Formula	NRAD Formula	NRMD Formula
R.S. ½-s Nitrocellulose (dry)	8.0	8.0	8.0	8.0
Nonoxidizing Alkyd Resin (100% basis)	–	–	12.0	–
Maleic Hard Resin	–	–	–	12.0
Dibutyl Phthalate	–	–	–	4.0
Ethanol	–	4.3	4.3	4.3
Solvent	92.0	41.7	35.7	33.7
Toluene	–	23.0	20.0	19.0
Xylene	–	23.0	20.0	19.0
Total Parts by Weight	100.0	100.0	100.0	100.0

(Butyl Acetate = 100)

UCAR® Ester EEP as a Polymerization Solvent for an Acrylic Resin

Monomer Composition

Ingredient	Weight Percent
Styrene	30.8
Butyl Acrylate	38.2
Hexoxy Ethyl Acrylate	15.7
Acrylic Acid	3.2
Initiator(1)	4.4
Solvent	7.7
Total	100.0

Results

Polymerization Solvent	Polymerization Temperature, °C	Average Molecular Weight	Solids,(2) % by Wt	Viscosity,(3) cP
Methyl n-Amyl Ketone	155	19.480	70	3440
UCAR® Ester EEP	175	13.739	70	3150
"Exxate"(4) 600	171	17.592	70	3850

(1) "Luperox" 500R (Pennwalt)
(2) Polymerization solids were ~81%, reduced to 70% for viscosity studies
(3) Brookfield model LVT
(4) Exxon

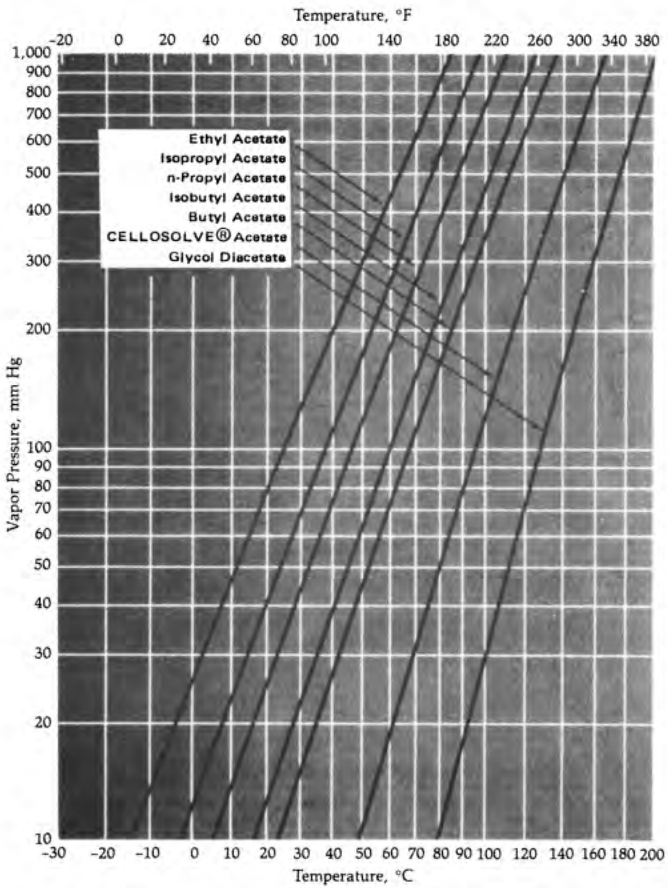
Electrostatic Application

Glycol Ether Esters	Resistivity, megohms
Methyl CELLOSOLVE Acetate	0.2
Butyl PROPASOL Solvent	0.45
Methyl PROPASOL Acetate	1.8
Butyl CELLOSOLVE Acetate	3.0
CELLOSOLVE Acetate	4.0
UCAR Ester EEP	20.0

(continued)

Table 15.49: (continued)

Vapor Pressures of Esters vs Temperature



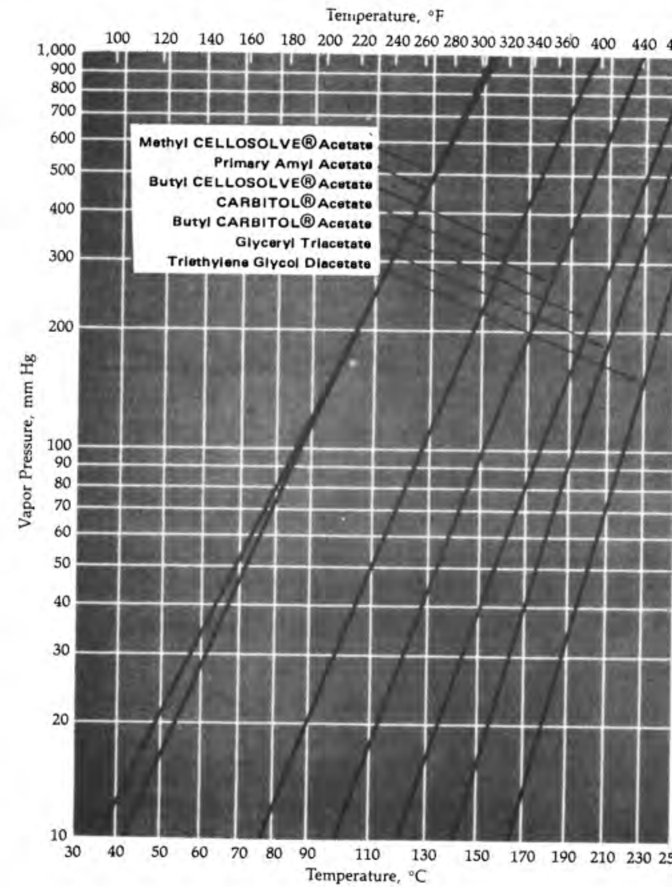
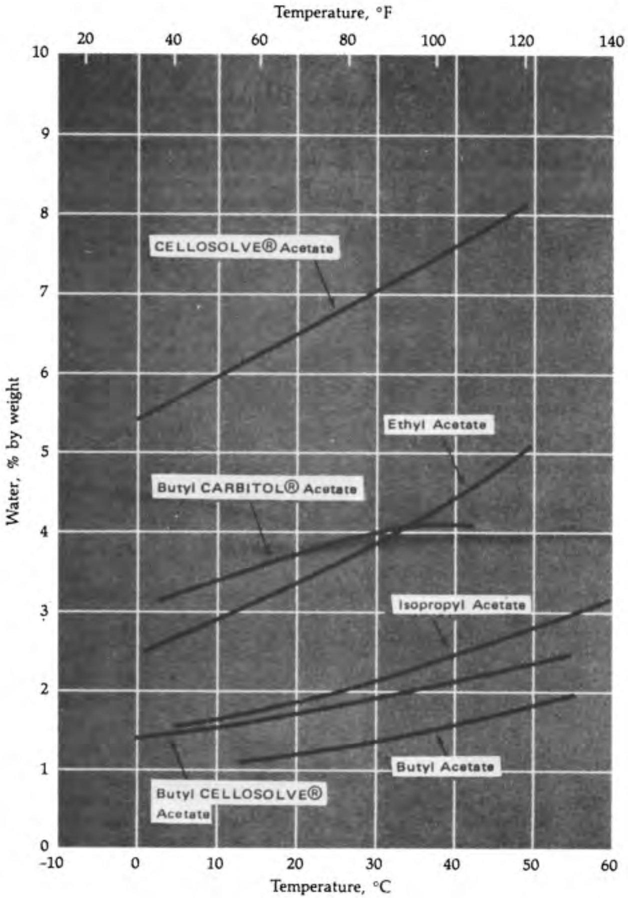


Table 15.49: (continued)

Solubilities of Water in Esters



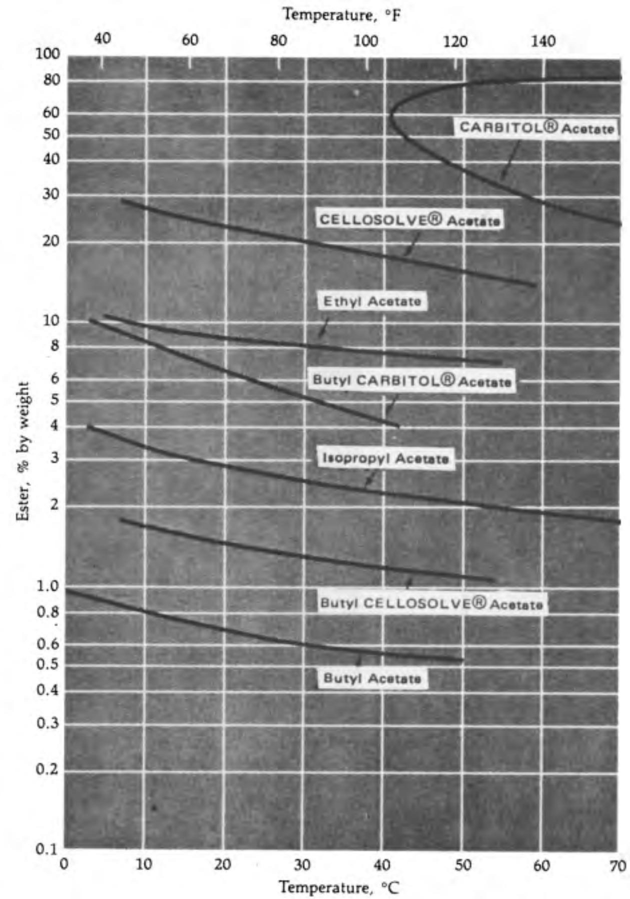


Table 15.49: (continued)

Relative Evaporation of Solvents

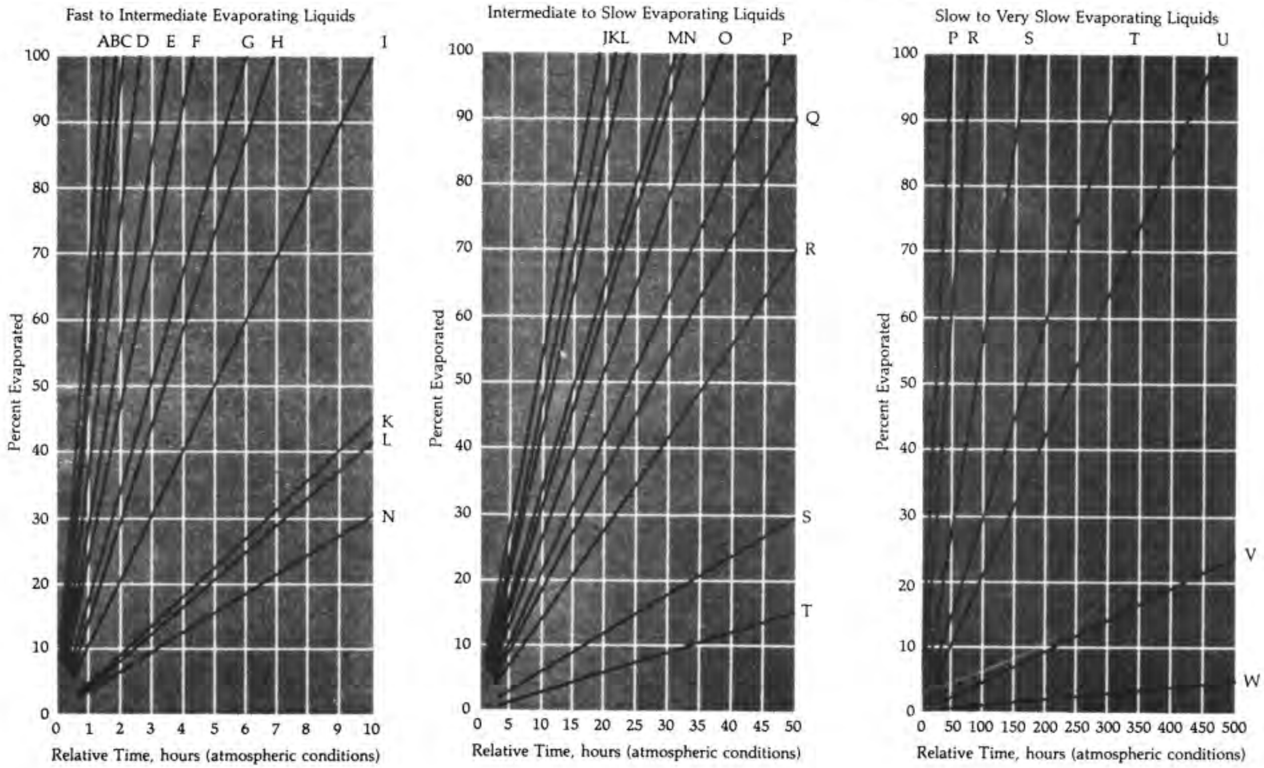


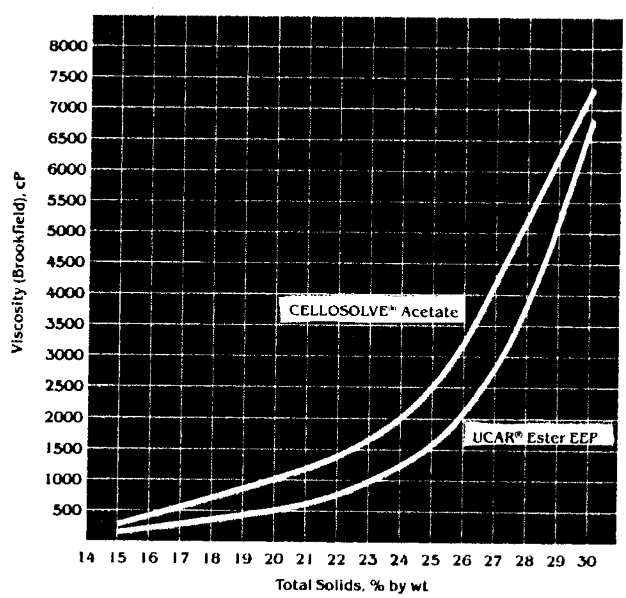
CHART KEY

- **A** Ethyl Acetate
- **B** Methyl Ethyl Ketone
- **C** Isopropyl Acetate
- **D** Ethanol, Anhydrous
- **E** Propyl Acetate
- **F** Isopropanol, Anhydrous
- **G** Methyl Isobutyl Ketone
- **H** Isobutyl Acetate
- **I** Butyl Acetate
- **J** Isobutanol
- **K** Butanol
- **L** Primary Amyl Acetate
- **M** CELLOSOLVE Solvent
- **N** Methyl CELLOSOLVE Acetate
- **O** Primary Amyl Alcohol
- **P** CELLOSOLVE Acetate
- **Q** Diisobutyl Ketone
- **R** Diacetone Alcohol (A/F)
- **S** Butyl CELLOSOLVE
- **T** Butyl CELLOSOLVE Acetate
- **U** Glycol Diacetate
- **V** CARBITOL Acetate
- **W** Butyl CARBITOL Acetate

(continued)

Table 15.49: (continued)

Viscosity of UCAR® Phenoxy Resin PKHH Solutions



Evaporation Profiles in an Automotive Refinish Thinner

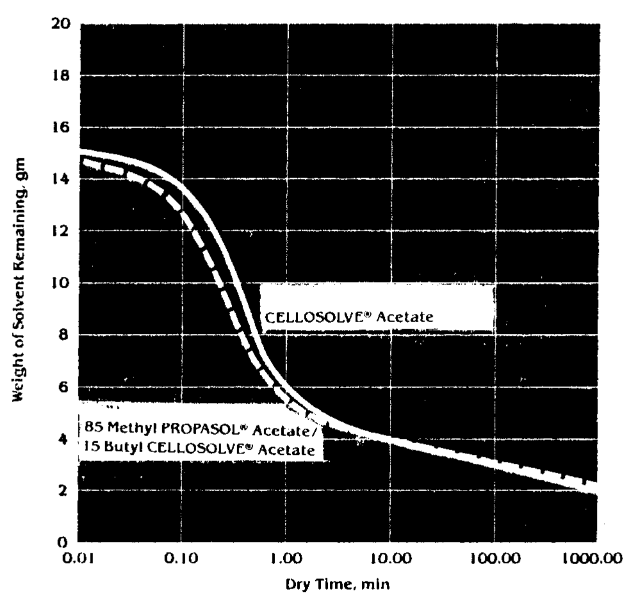


Table 15.50: Emery Methyl Esters *(63)*

	SPECIFICATIONS					TYPICAL COMPOSITION[1]								
						Saturated Esters							Unsaturated Esters	
	Acid Value Max	Sap. Value	Iodine Value max. (range)	Color % Trans 440/550 nm., min.	Typical Melting Point, °C	Caproate C_6	Caprylate C_8	Caprate C_{10}	Laurate C_{12}	Myristate C_{14}	Palmitate C_{16}	Stearate C_{18}	Oleate C_{18}	Linoleate C_{18}
EMERY® 2209 Methyl Caprylate-Caprate	0.5	330-336	0.4	95/–	-30	3	55	40	2					
EMERY® 2296 Methyl Laurate 96	0.5	258-263	0.5	95/–	5			2	96	2				
EMERY® 2290 Methyl Laurate 90	0.5	258-262	0.5	95/–	2			2	90	8				
EMERY® 2270 Methyl Laurate 70	0.5	251-255	0.5	95/–	-1			1	70	28	1			
EMERY® 2214 Methyl Myristate 95	1.0	230-234	0.6	92/–	17				3	95	2			
EMERY® 2216 Methyl Palmitate 95	0.2	206-210	0.2	92/–	27					2	95	3		
EMERY® 2218 Methyl Stearate 95	0.5	186-192	1	71/98	36						4	95	1	
EMERY® 2219 Methyl Oleate	4.0	188-192	(68-88)	71/98	18						4	24	58	14
EMERY® 2252 Methyl Coconate	1.0	250-260	4-11	85/min	4		8	7	48	17	9	2	7	2
EMERY® 2253 Methyl Coconate	0.5	250-260	(7-11)	71/98[2]	4		8	7	48	17	9	2	7	2
EMERY® 2254 Stripped Methyl Coconate	1.0	237-247	(5-10)	90/–	—			Tr	54	22	11	3	8	2
EMERY® 2255 Methyl Palm Kernalate	1.0	230-240	14-20	90/–			.25	1.5	50	17	9.5	3	16	3

[1] *Typical compositions determined by GLC analysis, AOCS Ce 1-62. These compositions are not manufacturing specifications.*
[2] *Not a specification.*
[3] *Color. Gardner 1963, max.*

Table 15.51: Procter & Gamble Methyl Esters *(39)*

Chemical Properties	CE-618*	CE-810	CE-1095	CE-1218	CE-1270	CE-1290	CE-1295	CE-1618	CE-1897
Saponification Value			295-305 (302)						195-205
Acid Value	1.0 max (0.6)	0.5 max (0.2)	0.5 max (0.3)	1.0 max (0.7)	0.5 max (0.2)	0.5 max (0.1)	0.3 max (0.1)	1.5 max	1.0 max
Iodine Value	14 max (5)	0.6 max (0.2)	0.6 max (0.3)	(8.9)	0.8 max (0.1)	0.8 max (0.1)	0.10 max (0.07)	60-70	85-95
Moisture, (%, KF)	0.1 max (0.05)	0.15 max (0.06)	0.15 max (0.04)	0.1 max (0.04)	0.05 max (0.03)	0.10 max (0.04)	0.05 max (0.03)	0.1 max	0.1 max
Physical Properties									
Specific Gravity 25/25 C	25 C (0.864) 25 C	25 C (0.870) 25 C	25 C (0.874) 25 C	25 C (0.866) 25 C	25 C (0.877) 25 C	25 C (0.867) 25 C	25 C (0.866) 25 C		
Melting Point (C)	(-4)	(-29)	(-14)	(10)	(0)	(5)	(6)		
%Transmittance @ 460 nm	90 min (94)	95min (99)	95 min (98)	85 min (94)	96 min (98)	95 min (99)	95 min (99)	80 min	90 min
Composition (GC%)									
C6	(0.5)	6.0 max (4)							
C8	7-9.5 (7.2)	51-58 (55.9)	(0.4)		(0.0)	(0.0)	0.3 max (0.0)		
C10	(6.2)	34-42 (39.3)	95.0 min (96.6)	0-3 (0.4)	1.0 max (0.3)	1.5 max (0.4)	2.5 max (0.5)		
C12	44.0-49.9 (47.3)	1.0 max (0.5)	(1.7)	52-57 (55.6)	70.5-74.5 (73.0)	90-94 (91.7)	95 min (98.1)	0.5 max	
C14	(17.3)		(0.2)	19-24 (20.9)	24-29 (26.3)	6-9 (7.8)	2.5 max (1.4)	1.0 max	1.0 max
C16	5.5-10.0 (9.7)			8-12 (10.2)	1.0 max (0.2)	0.8 max (0.0)	0.5 max (0.0)	25-32	0.2
C18	(7.8)			9-15 (12.3)				8	11
C18=1								53	73
C18=2								11	14
CAS No.	67762-37-2	67762-39-4	110-42-9	67762-26-9	67762-40-7	67762-40-7	111-82-0		

*Not inventoried, requires negotiated lead time

Table 15.52: Stepan Esters *(68)*

PRODUCT	INCI NOMENCLATURE	FORM @ 25°C	APPLICATIONS
ALCOHOL ESTERS			
KESSCO IPM	ISOPROPYL MYRISTATE	Liquid	IPM has a dry, velvety, non-oily feel due to its ready absorption into skin. Generally used in premium formulations for velvety emolliency.
KESSCO IPP	ISOPROPYL PALMITATE	Liquid	IPP is a dry, soft non-oily emollient generally used in economical formulations. Excellent solvent for mineral oil, silicone and lanolin.
KESSCO OCTYL PALMITATE	OCTYL PALMITATE	Liquid	Dry, light, silky emollient. Enhances gloss in hair grooming products. Can be used as a binder in pressed powder makeup.
KESSCO OCTYL ISONONANOATE	OCTYL ISONONANOATE	Liquid	Very dry, non-oily properties that allow the skin to breathe. Has the lowest freeze point (-30°C) of all alcohol esters. May be used in antiperspirants, hair sprays and creams/lotions.
KESSCO ICS	ISOCETYL STEARATE	Liquid	Premium emollient recommended for make-up formulations seeking a dry velvety feel.
KESSCO BS	BUTYL STEARATE	Liquid	Wetting agent for pigments and a fragrance solubilizer.
KESSCO 653	CETYL PALMITATE	Flake	Cetyl Palmitate is a waxy ester that imparts good skin feel properties to cosmetics. It is used as a base in stick cosmetics and as an emollient thickener in creams and lotions.
KESSCO 654	CETYL MYRISTATE	Flake	Similar to Kessco 653 but lower melting point (47-53°C).
GLYCEROL ESTERS			
KESSCO GMO	GLYCERYL OLEATE	Liquid	Effective water-in-oil emulsifier. Often used in bath oils as a lubricant and spreading agent. Imparts slip to creams.
KESSCO GDL	GLYCERYL DILAURATE	Solid	Semi-solid ester recommended for free flowing lotions. Imparts slight emolliency.
KESSCO GMS PURE	GLYCERYL STEARATE	Flake	High purity ester containing no soaps. Acts simultaneously as an emulsifier, opacifier and bodying agent. Used in creams, lotions, antiperspirants, hair care products and sunscreens.
KESSCO GMS 63F	GLYCERYL STEARATE	Flake	Emulsifier for creams and lotions
KESSCO GMS, S.E./A.S.	GLYCERYL STEARATE (and) PEG 100 STEARATE	Flake	Excellent emulsifier for low pH (3-5) systems. Is relatively insensitive to electrolytes in antiperspirants and cream rinses.
KESSCO GMS S.E. KESSCO GMS 24 S.E.	GLYCERYL STEARATE S.E. GLYCERYL STEARATE S.E.	Flake Flake	The S.E. grade allows the formulator to utilize GMS as a primary emulsifier for oil-in-water systems at a pH of 5-9. Anionic modified for broader emulsification properties.
KESSCO GDS	GLYCERYL DISTEARATE	Flake	Emulsifier with extremely low HLB compared to KESSCO GMS PURE, but with similar functionality.
SPECIALTIES			
STEPAN TAB-2 FLAKE STEPAN SAB-2	DI(HYDROGENATED) TALLOW PHTHALIC ACID AMIDE DI-STEARYL PHTHALIC ACID AMIDE	Flake Flake	Emulsion and suspension product for triglycerides, mineral oil, and silicones.
KESSCO CETYL ALCOHOL	CETYL ALCOHOL	Flake	Emollient, emulsion stabilizer, and viscosity modifier for skin and hair conditioners.

(continued)

Table 15.52: (continued)

PRODUCT	INCI NOMENCLATURE	FORM @ 25°C	APPLICATIONS
GLYCOL ESTERS			
KESSCO EGMS	GLYCOL STEARATE	Flake	Excellent pearlizing agent for shampoos and liquid hand soap.
KESSCO EGMS 70	GLYCOL STEARATE	Flake	Excellent pearlizing agent recommended for use in low solids formulations because it tends to increase viscosity.
KESSCO EGDS	GLYCOL DISTEARATE	Flake	Pearlizing agent for shampoos, handsoaps and bubble baths where no additional viscosity is required.
KESSCO EGAS	GLYCOL STEARATE (and) STEARAMIDE AMP	Flake	Pearlizing and bodying agent that imparts a soft, smooth skin feel to formulations due to the presence of a small amount of amide.
KESSCO DGMS KESSCO DGDS	PEG-2 STEARATE PEG-2 DISTEARATE	Flake Flake	Generally used as opacifiers in shampoos and lotions. Imparts emolliency and adds body to these types of formulations.
KESSCO DGS NEUTRAL	PEG-2 STEARATE	Flake	Used as an emulsifier and opacifier in creams and lotions.
KESSCO DGS S.E.	PEG-2 STEARATE (and) STEARIC ACID	Flake	Emulsifier for hair care products, creams, lotions, antiperspirants and sunscreens.
KESSCO PGMS PURE	PROPYLENE GLYCOL STEARATE	Flake	Good auxiliary emulsifiers and opacifiers. Has a melting point near body temperature and is used in suppositories, lipsticks and sunscreens.
KESSCO PGML E	PROPYLENE GLYCOL LAURATE	Liquid	Emollient and auxiliary emulsifier. Imparts a soft, velvety feel to cosmetic products.
KESSCO PGMS 8615	PROPYLENE GLYCOL STEARATE S.E.	Flake	Emulsifier for creams and lotions.
KESSCO PGMS 534F	PROPYLENE GLYCOL STEARATE	Flake	Food grade auxiliary emulsifier. Also used in creams, lotions and suppositories.
POLYETHYLENE GLYCOL ESTERS			
KESSCO PEG 200-6000 MONO AND DILAURATES	PEG-4 to PEG-150 LAURATE AND DILAURATE	Liquids to Solids	Non-toxic and non-irritating nonionic emulsifiers that cover a wide HLB range They act as viscosity modifiers, emollients, opacifiers, spreading agents, wetting and dispersing agents. They may be used in lotions, creams, make-up, bath oils, ointments, shampoos, conditioners, suppositories and sunscreen products.
KESSCO PEG 200-6000 MONO AND DIOLEATES	PEG-4 TO PEG-150 OLEATE AND DIOLEATE	Liquids to Solids	
KESSCO PEG 200-6000 MONO AND DISTEARATES	PEG-4 and PEG-150 STEARATE AND DISTEARATE	Solids	
DREWPOL 3-1-0 DREWPOL 6-1-0 DREWPOL 10-4-0 DREWPOL 10-10-0	POLYGLYCERYL-3 OLEATE POLYGLYCERYL-6 OLEATE POLYGLYCERYL-10 TETRAOLEATE POLYGLYCERYL-10 DECAOLEATE	Liquid Liquid Liquid Liquid	The DREWPOL polyglycerol esters comprise a relatively new class of emulsifiers for the cosmetic industry. These products range from hydrophilic monoesters to lipophilic deca-esters. The polyglycerol esters are effective nonionic emulsifiers in both oil-in-water and water-in-oil emulsions.
SPECIALTY OILS			
NEOBEE M-5 COSMETIC WECOBEE S WECOBEE M	CAPRYLIC/CAPRIC TRIGLYCERIDE HYDROGENATED VEGETABLE OIL HYDROGENATED VEGETABLE OIL	Liquid Flake Solid	The Neobee and Wecobee oils are derived from edible vegetable oils. The Neobee's are used as emollients in creams and lotions. The Wecobee's are used as a replacement for cocoa butter in cosmetic products.

KESSCO®, DREWPOL®, NEOBEE®, and WECOBEE® are registered trademarks of the Stepan Company.

ADIPATES

Table 15.53: Mixture of Dimethyl Adipate and Dimethyl Glutarate *(11)*

$H_3COOC(CH_2)_xCOOCH_3$ x = 3-4

This mixture of dibasic esters is used as a high boiling solvent and as an intermediate.

Diester Content, Wt. % Minimum	99	Water Content, Wt. % Maximum	0.5
Dimethyl Adipate, Wt. %	30-45	Average Molecular Weight	165
Dimethyl Glutarate, Wt. %	55-70	Specific Gravity	1.082 - 1.090 @ 25/25°C
Dimethyl Succinate, Wt. % Max.	3	Distillation Range, °C	210 -225
Solubility Parameters (Hansen System)		Evaporation Rate BuAc = 100	<1
Polar Bonding	3.29	Viscosity @ 25°C, Centipoise	2.38
Hydrogen Bonding	4.02	Freezing Point	-13°C (Approx.)
Non-Polar Bonding	7.03	Flash Point	219°F Closed Cup
Solubility Parameter	8.75		

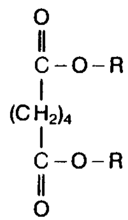
Table 15.54: Mixture of Dimethyl Adipate, Dimethyl Glutarate and Dimethyl Succinate *(11)*

$H_3COOC(CH_2)_xCOOCH_3$ x = 2-4

This dibasic ester mixture is used as a high boiling solvent in industrial and automotive coatings.

Diester Content, Wt. % Minimum	99
Dimethyl Adipate, Wt. %	20-30
Dimethyl Glutarate, Wt. %	40-60
Dimethyl Succinate, Wt. %	20-30
Solubility Parameters (Hansen System)	
Polar Bonding	3.4
Hydrogen Bonding	4.1
Non-Polar Bonding	8.5
Solubility Parameter	10.1
Water Content, Wt. % Maximum	0.5
Average Molecular Weight	160
Specific Gravity	1.082 - 1.090 @ 25/25°C
Distillation Range, °C	196 - 225
Evaporation Rate BuAc = 100	<1
Viscosity @ 25°C, Centipoise	2.39
Freezing Point	-20°C (Approx.)
Flash Point	212°F Tag Closed

Table 15.55: Dialkyl Adipate *(75)*



R = mixed, C_7 & C_9 predominantly linear alkyl

SANTICIZER 97

Table A. Properties

Molecular Weight	370
• Acidity (meq/100 gm. max)	0.25
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	50
• Moisture (KF in Methanol) %, max.	0.10
• Refractive Index (@25°C)	1.441 – 1.447
• Specific Gravity (25°/25°C)	0.916 – 0.924
Density (@ 25°C) ca. lbs./gal.	7.7
Crystallizing Point (°C)	– 13
Boiling Point @ 10mm Hg, °C	224
Vapor Pressure (mm Hg)	
@ 200°C	3.3
@ 250°C	27
Viscosity (Centistokes) @ 25°C	12.8
Surface Tension @ 25°C (dynes/cm)	30.3
Flash Point (C.O.C.) [°F.]	400
Fire Point (C.O.C.) [°F.]	450
Solubility In Water @ 25°C,%	<0.01
CAS Number	68515-75-3

• Specification

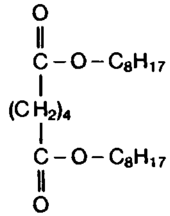
Table B. Comparison of Seven Commercial Low-temperature Plasticizers at Three Levels in PVC

	Sant 97	DOA	DNODA	DINA	DIDA	DOZ	DOS
Flex Temperature, °C., Clash-Berg Method							
35 PHR	–33.5	–29.1	–33.4	–27.0	–26.7	–32.0	–32.2
50 PHR	–56.7	–52.9	–55.0	–48.8	–49.4	–54.4	–54.7
67 PHR	–67.5	–64.3	–61.0	–62.0	–62.2	–66.3	–68.5
Carbon Volatility, % Plasticizer lost, 24 hrs. at 87°C.							
35 PHR	10.2	13.2	9.8	5.5	3.2	4.3	2.1
50 PHR	9.7	13.3	9.6	5.4	3.5	3.8	2.1
67 PHR	9.8	13.1	9.7	5.0	3.0	3.8	2.1
Shore A Hardness, 10 sec. reading							
35 PHR	92	91	93	95	96	92	94
50 PHR	82	81	83	86	90	82	85
67 PHR	71	71	72	76	80	73	74
Water Sensitivity, 24 hrs. at 50°C., % water absorbed/% soluble matter lost							
35 PHR	.32/.07	.35/.07	.36/.08	.35/.05	.37/.08	.32/.04	.31/.02
50 PHR	.31/.18	.31/.16	.31/.20	.34/.13	.32/.16	.25/.09	.23/.08
67 PHR	.33/.20	.33/.25	.32/.22	.36/.15	.31/.15	.31/.09	.26/.07
Kerosene Extract, % Plasticizer lost, 24 hrs. at 23°C.							
35 PHR	24.6	13.5	30.4	23.4	49.8	19.4	31.4
50 PHR	74.2	42.5	68.3	71.8	73.0	71.8	74.7
67 PHR	77.0	72.7	76.3	75.7	80.4	74.9	82.8
Loop Compatibility – Degree of exudation: 0 = dry, no exudation; 10 = dripping wet							
35 PHR 4 hours	5	4	5	5	5	5	5
1 day	7	5	7	7	7	7	7
1 week	5	0	5	7	7	7	7
50 PHR 4 hours	7	5	7	7	7	7	7
1 day	7	7	8	8	8	8	8
1 week	0	0	0	7	8	5	5
67 PHR 4 hours	7	6	7	7	7	7	7
1 day	6	5	6	7	8	7	7
1 week	0	0	0	0	6	0	0
Cumulative rating (lower is better)	44	32	45	55	63	53	53

Table C. Adipate Performance in Plastisols (65 PHR)

Brookfield viscosity, poises, 50 RPM (HAT #6 Spindle)		Santicizer® 97	Dioctyl adipate
23°C	Initial	8	12
	7 days	10	20
	28 days	12	26
40°C	Initial	8	10
	7 days	17	32
	28 days	24	43
50°C	Initial	8	11
	7 days	31	42
	28 days	51	62
Severs Viscosity poises	10 psi	8	8
	50 psi	7	7
	100 psi	7	6

Table 15.56: Dioctyl Adipate *(75)*



DOA

Table A. Properties

Molecular Weight	371
• Acidity (meq/100 gm. max)	0.25
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	25
• Moisture (KF in Methanol) %, max.	0.10
• Odor	Mild
• Refractive Index (@25°C)	1.444 – 1.448
• Specific Gravity (25°/25°C)	0.921 – 0.927
Density (@ 25°C) ca. lbs./gal.	7.72
Crystallizing Point (°C)	< – 70
Pour Point (°C)	– 65
Boiling Point @ 10mm Hg, °C	224
Vapor Pressure (mm Hg)	
@ 200°C	2.3
@ 250°C	32
Viscosity (Centistokes)	
@ 37.8°C	8.2
@ 98.9°C	2.4
Surface Tension @ 20°C (dynes/cm)	29
Thermal Expansion Coefficient @ 10° – 40°C (cc/cc/°C)	0.00078
Flash Point (C.O.C.) [°F.]	377
Fire Point (C.O.C.) [°F.]	450
Solubility In Water @ 25°C,%	<0.01
CAS Number	103-23-1

• Specification

Table B. Dioctyl Adipate Performance in PVC (40 Mil Sheet)

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility (% Lost) (Activated Carbon)	14	13	14
Low-temperature Flex, Tf °C	– 46	– 66	< – 70
Water immersion (24 hours):			
% soluble matter lost	0.05	0.10	0.07
% water absorbed	0.40	0.66	0.82
Kerosene extraction (% plasticizer lost)	19	>70	>70
Shore "A" Hardness	83	67	48
Migration, Linde Silica:			
1 day	5.1	7.5	11.0
3 days	9.5	13.5	22.0
7 days	14.6	21.0	28.0
Tensile, p.s.i.	2560	1870	1090
Elongation, %	390	450	460
Modulus @ 100% Elongation	1390	730	380
Flammability (Limiting O_2 Index)*	22.6	21.0	19.6
Heat Stability	Good	Good	Good
Migration Resistance to Nitrocellulose	Poor	Poor	Poor
Fluxing Rate	Fair	Fair	Fair
Electrical Properties	Fair	Fair	–

*The Oxygen Index Test results are not intended to reflect performance of these or any other materials under actual fire conditions. Each user should determine independently whether potential fire hazards are associated with the finished product and whether DOA is suitable for the particular use.

Table C. Dioctyl Adipate Performance in Plastisol Formulation

Viscosity, poises Brookfield HAT #6 Spindle 50 PRM		65 PHR
23°	Initial	12
	7 Days	20
	28 Days	26
40°	Initial	10
	7 Days	32
	28 Days	43
50°	Initial	11
	7 Days	42
	28 Days	62
Severs	10 psi	8
	50 psi	7
	100 psi	6
Yield value, dynes/cm^2		20
Flow Index		0.6
Gel Temperature, °C		80
Fusion, Relative Temperature, °C		175
*Air-release Rate		Fast
*Resilience, steel ball, inches		10.9

*Efficiency Conc. Adj. to "60" Shore A Hardness

OXALATES

Table 15.57: Diethyl Oxalate *(2)*

Ethyl Ethanedioate $(COOC_2H_5)_2$

Diethyl oxalate is a water-white liquid with a mild odor. It is used as a slow-evaporating nitrocellulose solvent, in special lacquers for fixing rare salts on the cathode of radio tubes and in organic synthesis.

Acidity (as oxalic)	0.05% by wt, max
Blush resistance at 60° F (10% ½ sec. R.S. nitrocellulose solution)	Clear 90% Relative humidity Blush
Coefficient of expansion	
per 1°F	0.00056
per 1°C	0.00101
Color	Water-white
Dilution ratio	
Toluol	3.5
Petroleum naphtha	0.7
Distillation range	
Below 180°C	None
Below 182°C	Not more than 10%
Below 188°C	Not less than 90%
Above 190°C	None
Dryness at 20°C	Miscible without turbidity with 20 volumes 60° Bé gasoline
Flash point (Open Cup)	168°F
Non-volatile matter	0.005 gm per 100 cc, max
Odor	Mild, non-residual
Purity	99% min
Specific gravity at 20/20°C	1.075–1.079
Water solubility at 25°C	10 cc solvent dissolves 1.5 cc water
Viscosity (10% ½ sec. R.S. nitrocellulose solution)	380 centipoises
Weight per gal at 20°C	8.96 lbs (approx)

Table 15.58: Dibutyl Oxalate *(2)*

$C_4H_9OOCCOOC_4H_9$

Dibutyl oxalate is a high-boiling, water-white liquid with a mild odor and having a tendency to hydrolyze and split off oxalic acid. It is miscible with most alcohols, ketones, oils and hydrocarbons, and is a solvent for benzyl abietate, cellulose esters and ethers, "Cumar" resins, ester gum, copal ester, "Glyptal" resins and mastic. It is used in nitrocellulose lacquers as a plasticizing solvent for the purpose of fixing rare earth salts on cathode elements, and in organic synthesis.

Acidity (as oxalic)	0.05% by wt, max
Blush resistant at 90°F (1.0% R.S. ½ sec. nitrocellulose solution)	Clear 90 Relative humidity Blush
Coefficient of expansion	
per 1°F	0.00053
per 1°C	0.00095
Color	Water-white
Dilution ratio	
Toluol	2.3
Petroleum naphtha	1.0
Distillation range:	
Below 240°C	Not more than 5%
Below 248°C	Not less than 90%
Above 255°C	None
Dryness at 20°C	Miscible without turbidity with 20 volumes 60° Bé gasoline
Freezing point	−30.0°C
Non-volatile matter	0.005 gm/100 cc, max
Solubility of water in solvent at 25°C	0.5% by vol
Specific gravity at 20/20°C	0.980–0.993
Viscosity (10% ½ sec. nitrocellulose solution)	800 centipoises
Weight per gal at 20°C	8.24 lbs

Table 15.59: Diamyl Oxalate *(2)*

$$C_5H_{11}OOCCOOC_5H_{11}$$

Diamyl oxalate is a colorless, oily liquid miscible with most lacquer solvents, oils and hydrocarbons. It is a solvent for ester gum, copal ester, "Cumar" resins, alkyd resins, mastic, nitrocellulose and shellac. It is used as a plasticizer and in paint and varnish removers. Like other oxalates, it has a tendency to hydrolyze.

Boiling point	265°C.
Flash point	116°C.
Specific gravity	0.97

LACTATES

Table 15.60: Methyl Lactate *(2)*

$$CH_3CH(OH)COOCH_3$$

Methyl lactate is a water-white liquid, completely miscible with water and most organic liquids. It is a solvent for nitrocellulose, cellulose acetate, cellulose acetobutyrate and cellulose acetopropionate. It is used in the manufacture of lacquers and dopes where it contributes high tolerance for diluents, good flow and blush resistance.

Acidity (as lactic)	0.15% by wt, max
Boiling point	144.8°C
Color	Water-white
Distillation range:	
Below 115°C	None
Between 141°C and 145°C	Not less than 60%
Above 155°C	None
Flash point	51.7°C
Heat of combustion	4778 calories per gram
Freesing point	Approx 66°C
Non-volatile matter	0.01 gram per 100 cc, max
Purity	95% min
Refractive index at 20°C	1.4131
Specific gravity at 20/20°C	1.087 to 1.097
Water at 20°C	No turbidity wben mixed with 19 volumes of 60° B6 gasoline
Weight per gal at 68°F	9.09 lbs

Table 15.61: Ethyl Lactate *(2)*

$$CH_3CH(OH)COOC_2H_5$$

Ethyl lactate is a colorless and almost odorless liquid, which, upon evaporation, will sometimes develop a disagreeable odor. This is owing to the lactides, or inner anhydrides, contained in the lactic acid made by fermentation. It is miscible with water, alcohols, ketones, esters, hydrocarbons and oils. Ethyl lactate will dissolve cellulose acetate and nitrate and many of the ethers of cellulose. It is also a solvent for basic dyes, alkyd resins, kauri, manila, pontianac, rosin, shellac and vinyl resins. Ethyl lactate has high solvent power and equally high tolerance for nonsolvents and diluents. These exceptional properties are accounted for by the existence of both an alcohol and an ester group in its molecule.

Its rate of evaporation is slow but this is desirable for brushing lacquers. The presence of ethyl lactate in a solvent mixture imparts good working qualities and good flow, and permits the application of a thin coat on almost any surface. The resulting films are smooth and uniform, although at times the film will remain soft for a longer period than is anticipated. Its solvent action is slower than that of butyl or amyl acetate and the resulting solution has a high viscosity. However, it will tolerate two or three times as much nonsolvent or diluent. In fact, a solution of pyroxylin in ethyl lactate will tolerate the addition of 25 percent water without precipitation. As far as water tolerance is concerned it has no rival in the field of solvents. Ethyl lactate is useful as a lacquer solvent for cellulose nitrate, acetate and ethers. It is used in the preparation of stencil sheets, incandescent mantle lacquers and in laminated glass.

(continued)

Table 15.61: (continued)

Physical Properties and Specifications

Acidity (as lactic)	0.08%, max
Color	Water-white
Distillation range:	
Below 102°C	None
Below 139°C	Not more than 10%
Below 155°C	Not less than 90%
Above 173°C	None
Dryness	Miscible without turbidity with 20 vols 60° Bé gasoline at 20°C
Non-volatile matter	0.005 g/100 cc, max
Odor	Mild, non-residual
Purity	96% min
Specific gravity at $\frac{20°C}{20°C}$	1.020–1.036
Blush resistance at 90°F (10% ½-sec. R.S. nitrocellulose sol.)	Clear 80% Relative humidity Blush 85%
Coefficient of expansion	0.00058/1°F 0.00104/1°C
Dilution ratio	5.5 with toluene 0.8 with petroleum naphtha
Evaporation rate at 95°F	
Per cent	5 25 50 75 90 95
Minutes	4 23 47½ 73 92½ 101
Flash point	129°F. (approx)
Viscosity (10% ½-sec. R.S. nitrocellulose solution)	195 centipoises
Water solubility	Soluble in all proportions (25°C)

Table 15.62: Butyl Lactate *(2)*

$$CH_3CH(OH)COOC_4H_9$$

Butyl lactate is a colorless liquid having a mild odor. The commercial grade contains condensation products and its physical and chemical properties will vary. It is miscible with many of the lacquer solvents, diluents and oils. It will dissolve such substances as cellulose esters, "Cumar" resins, ester gum, copal ester, alkyd resins, mastic and shellac. It has a high tolerance for nonsolvents and it evaporates slowly. Its presence in a solvent mixture will impart brilliance, gloss, adhesion, flexibility and tenacity to the film. It is used as a solvent in lacquers, in stencil manufacture and in lithographic and printing inks. It is also used as an anti-skinning agent, as an intermediate, and in perfumes.

Purity	95% ester by wt, min
Specific gravity at $\frac{20°C}{20°C}$	0.974 to 0.984
Acidity (as lactic)	0.15% max
Water	No turbidity when mixed with 19 vols of 60° Bé gasoline at 20°C
Non-volatile matter	0.01 g per 100 cc, max
Color	Water-white
Distillation range	
Below 140°C	None
Between 155°C and 195°C	Not less than 60 per cent
Between 187°C and 189°C	Not less than 90 per cent
Dry point	Not above 200°C
Molecular weight	146.11
Odor	Mild (No residual odor)
Flash point	71°C (159.8°F)
Freezing point	−43°C
Weight per gallon	8.15 lbs. (68°F)
Solubility in water	3.4% by vol (25°C)
Solubility of water in butyl lactate	13.0% by vol (25°C)
Refractive index	1.42162 (20°C)
Vapor pressure	0.4 mm Hg (20°C)
Heat of vaporization	77.4 cal/g (20°C)

Table 15.63: Amyl Lactate *(2)*

$CH_3CH(OH)COOC_5H_{11}$

Amyl lactate is a colorless to pale yellow nontoxic liquid with an odor like that of brandy. Its composition varies containing lacticides among other things. It is miscible with alcohols, ketones, esters, hydrocarbons, oils, and so forth. It is a solvent for cellulose ethers, "Cumar" resins, copal esters, mastic, nitrocellulose and shellac, and will dissolve alkyd resins when combined with alcohol. It is used as a plasticizer for cellulose derivatives.

Acidity (as lactic)	0.05% by wt., max.
Color	Water-white
Distillation range at 20 mm.	100% between 75°-150°C.
Flash point	175°F.
Purity	At least 95%, min.
Specific gravity at 20°C.	0.954-0.966
Weight per gal.	7.99 lbs.

Table 15.64: Physical Properties of Lactates *(2)*

Lactic Esters

	B.P.		Sp. Gr.	Refractive Index	Saponification Value	
	°C	Mm.			Calcd.	Found
Methyl	144.8	760	d^{19} 1.0898	n_D^{25} 1.4132[b]		
Ethyl	154.5	760	d^{19} 1.0308	n_D^{25} 1.4121[b]		
n-Propyl	86	40	d_{20}^{20} 0.996	n_D^{25} 1.4167[b]		
Isopropyl	166–8	760	d_{20}^{20} 0.998	n_D^{25} 1.4082[b]		
n-Butyl	185	760	d_{20}^{20} 0.973	n_D^{25} 1.4214[b]		
Isobutyl	96	40	d_{20}^{20} 0.971	n_D^{25} 1.4183[b]		
sec-Butyl[c]	180	760	d_{20}^{20} 0.974			
n-Amyl	112	40	d_{20}^{20} 0.952	n_D^{25} 1.4254[b]		
Isoamyl	82	7	d_{25}^{25} 0.9614	n_D^{25} 1.4240	350	353
n-Hexyl	75	2	d_{25}^{25} 0.9533	n_D^{25} 1.4290	322	322
2-Ethyl butyl	104	12	d_{25}^{25} 0.9615	n_D^{25} 1.4307	322	321
2-Ethyl hexyl	112	3.6	d_{25}^{25} 0.9405	n_D^{25} 1.4358	277	278
Lauryl	150–3	4	d_{25}^{25} 0.9108	n_D^{25} .14433	217	212
Phenyl ethyl	124	4	d_{25}^{25} 1.0979	n_D^{25} 1.5073	289	293
Glycol[d]	140	10	d_{25}^{25} 1.1967	n_D^{25} 1.4452	419	413
Glycerol[d]	175–80[e]	2				
Benzyl	134	4	d_4^{20} 1.1355	$n_D^{20.5}$ 1.5049		
Stearyl	180[e]	2				

Acetoxypropionate Esters

	B.P.		Sp. Gr.	Refractive Index	Saponification Value	
	°C	Mm.			Calcd.	Found
Methyl	171.5	760	d_4^{20} 1.088	n_D^{20} 1.4111		
Ethyl	177	733	d^{17} 1.0458	n_D^{25} 1.4085[b]		
n-Propyl	195–6	766	d_{25}^{25} 1.0163	n_D^{25} 1.4123		
Isopropyl	182–3	765	d_{25}^{25} 0.9920	n_D^{25} 1.4058		
n-Butyl	213–4	767	d_4^{20} 1.0001	n_D^{25} 1.4147		
Isobutyl	205	763	d_{25}^{25} 0.9952	n_D^{25} 1.4140		
n-Amyl	226–7	763	d_{25}^{25} 0.9822	n_D^{25} 1.4199		
Isoamyl	221–2	763	d_{25}^{25} 0.9838	n_D^{25} 1.4190		
n-Hexyl	135	17	d_{25}^{25} 0.9770	n_D^{25} 1.4232	519	519
2-Ethyl butyl	127	14	d_{25}^{25} 0.9822	n_D^{25} 1.4245	519	522
2-Ethyl hexyl	145	13	d_{25}^{25} 0.9629	n_D^{25} 1.4298	460	462
Lauryl	165	4	d_{25}^{25} 0.9304	n_D^{25} 1.4373	373	370
Phenyl ethyl	139	4	d_{25}^{25} 1.0983	n_D^{25} 1.4896	475	476
Acetoxyethyl (glycol monolactate diacetate)	145	10	d_{25}^{25} 1.1489	n_D^{25} 1.4297		
Benzyl	145.8	4	d_4^{20} 1.1227	n_D^{25} 1.4874		
Glycerol monolactate triactetate[e]						

[a] Where no reference is given, the properties were determined by the authors.
[b] Properties not given in the reference but determined by the authors.
[c] Compounds not prepared by authors.
[d] Monolactate.
[e] Decomposed.

CARBONATES

Table 15.65: Diethyl Carbonate *(2)*

Ethyl Carbonate
DIATOL (contains 90% diethyl carbonate)

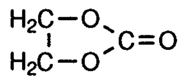
$(C_2H_5)_2CO_3$

Acidity (as carbonic)	0.02% by wt, max
Blush resistance at 90°F (10% ½ sec. R.S. nitrocellulose solution)	Clear 85% Relative humidity Blush 90%
Boiling point	180°C
Coefficient of expansion	
per 1°F	0.00066
per 1°C	0.00119
Color	Water-white
Dilution ratio	
Toluol	0.6
Petroleum Naphtha	0.4
Distillation range:	
Below 120°C	None
Below 128°C	Not less than 90%
Above 130°C	None
Dryness at 20°C	Miscible without turbidity with 20 vols 60° Bé gasoline
Evaporation rate at 95°F (in minutes)	
5%	1½
25%	7½
50%	14½
75%	24
90%	31½
95%	34½
Flash point	89°F
Freezing point	48.2°C
Non-volatile matter	Not more than 0.005 gm per 100 cc
Purity	98–100%
Solubility in water	69% by wt
Solubility of water in solvent at 25°C	1.4% by vol
Specific gravity at 20/20°C	0.973–0.977
Vapor pressure at 103°C	54 mm Hg
Weight per gal at 20°C	8.11 lbs (approx)

Table 15.66: JEFFSOL Carbonates *(48)*

JEFFSOL Ethylene Carbonate
(CAS 96-49-1)

STRUCTURE



Mol. wt. 88.06

DESCRIPTION

A low-melting point solid, practically odorless and colorless.

SALES SPECIFICATIONS

Appearance	Melt shall be clear and substantially free of suspended matter
Color, Pt-Co	40 max. (supercooled liquid)
Assay, wt. %[1]	99.5 min.
Ethylene glycol, wt. %	0.2 max.
Water, wt. %[2]	0.1 max.

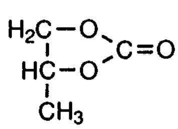
TYPICAL PROPERTIES

Boiling point, 760 mm Hg, °C	248.2
Flash point, PMCC, °C	160
Melting point, °C	36.4
Weight, lb/gal, 20°C	11.0
UEL, (v/v) at 200°C	26.8%
LEL, (v/v) at 200°C	4.5%
Autoignition temp.	447-450°C

[1]GC Assay on water free basis
[2]Karl Fisher Assay

JEFFSOL Propylene Carbonate
(CAS 108-32-7)

STRUCTURE



Mol. wt. 102.09

DESCRIPTION

A clear, mobile, hygroscopic liquid at room temperature.

SALES SPECIFICATIONS

Appearance	Clear and substantially free of suspended matter
Color, Pt-Co	40 max.
Assay, wt. %[1]	99.7 min.
PG, wt. %	0.2 max.
Water, wt. %[2]	0.1 max.

TYPICAL PROPERTIES

Boiling point, 760 mm, °C	242
Flash point, PMCC, °F	275
Melting point, °C	-49.2
Vapor pressure, mm Hg, 20°C	0.02
Weight, lb/gal, 20°C	10.1
Ash, wt. %	0.01 max.
Specific gravity, 20/20°C	1.203 min. 1.210 max.
UEL, (v/v) at 200°C	26.8%
LEL, (v/v) at 200°C	4.5%
Autoignition temperature	430°C

(continued)

Table 15.66: (continued)

Dielectric Constants of Mixtures

		JEFFSOL EC, WT %					
Solvent	**Temperature**	**0**	**20**	**40**	**60**	**80**	**100**
Benzene	25°C	2.27	9.47	21.2	38.6	62.8	Solid
	40°C	2.24	9.03	20.0	36.1	58.5	89.1
Methanol	25°C	32.6	39.1	47.4	58.6	74.0	Solid
	40°C	29.8	35.9	43.7	54.0	68.5	89.1
JEFFSOL PC	25°C	65.0	69.1	74.6	80.5	87.2	Solid
Water	25°C	78.5	80.5	81.6	83.3	86.4	Solid

JEFFSOL PC Solubility

Substance	**g Solute in 100 g JEFFSOL PC at 25°C**	**Substance**	**g Solute in 100 g JEFFSOL PC at 25°C**
Acetone	∞	Carbon tetrachloride	100
Benzene	∞	Castor oil	<1
n-Butanol	∞	Cellulose acetate	>10(30°C)
2-Butoxyethanol	∞	Cellulose acetate butyrate	>10(30°C)
Chloroform	∞	$CoCl_2 \cdot 6H_2O$	3.0(40°C)
Dibutyl sebacate	∞	$Co(NO_3)_2 \cdot 6H_2O$	25.4(40°C)
Diethylene glycol	∞	Coumarone-indene	>10(110°C)
Diethylene glycol monobutyl ether	∞	DDT	17
Diethylene glycol monomethyl ether	∞	Dioctyl sebacate	2
Diethyl ether	∞	Epichlorohydrin-bisphenol	>10(30°C)
Di(2-ethylhexyl) phthalate	∞	Ester gum	>10(120°C)
Dimethylformamide	∞	Ethyl cellulose	>10(145°C)
Ethanol	∞	Gum shellac	>10(175°C)
Ethyl acetate	∞	n-Heptane	4.1
Ethylene dichloride	∞	$HgCl_2$	21.0(40°C)
Ethylene glycol	∞	Lignin	>10(30°C)
Methanol	∞	Lindane	18
2-Methoxyethanol	∞	Methyl chloride	4.1(40°C)
Methyl ethyl ketone	∞	$NiCl_2 \cdot 6H_2O$	0.4(40°C)
Nonylphenol	∞	$Ni(NO_3)_2 \cdot 6H_2O$	5.8(40°C)
Ortho-nitrobiphenyl	∞	Nitrocellulose	>10(30°C)
Polyoxyethylene glycols (mol. wt. 400 and 600)	∞	Nylon	>10(190°C)
Propylene oxide	∞	Polyacrylonitrile	10(90°C)
JEFFSOL EC	∞	Polyoxyethylene glycols (mol. wt. 1000 and 4000)	>100
Toluene	∞	Polyvinyl chloride	>10(100°C)
Tricresyl phosphate	∞	Polyvinyl chloride-polyvinyl acetate	10(30°C)
Triethylene glycol di-2-ethyl hexoate	∞	Polyvinyl chloride-polyvinylidene chloride	10(130°C)
Xylene	∞	Polyvinylidene chloride-polyacrylonitrile	10(110°C)
		Rosin, dibasic acid modified	>10(120°C)
Acetylene	0.6(40°C)	Tri(2-ethylhexyl) phosphate	5
Alkyd resin, long oil-nonoxidizing	>10(60°C)	Urea	<1
Camphor	80	Water	8.3

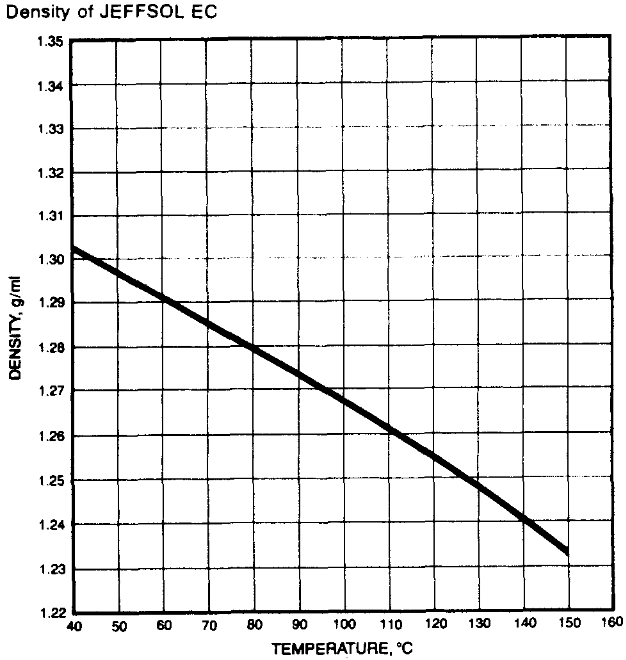
(continued)

Table 15.66: (continued)

JEFFSOL EC Solubility

Substance	g Solute in 100 g JEFFSOL EC at 40°C	Substance	g Solute in 100 g JEFFSOL EC at 40°C
Benzene	∞	Coumarone-indene	>10(190°C)
Butyl acetate	∞	Dibutyl sebacate	<2
Chloroform	∞	Dioctyl sebacate	<1
Dichloroethyl ether	∞	Di(2-ethylhexyl) phthalate	<2
Ethanol	∞	Epichlorohydrin-bisphenol	>10
Ethyl acetate	∞	Ester gum	>10(200°C)
Ethylene dichloride	∞	Gum shellac	>10(160°C)
Formamide	∞	$HgCl_2$	49
Methanol	∞	Lignin	>10
Methylene dichloride	∞	Naphthalene	15
Nonylphenol	∞	$Ni(NO_3)_2 \cdot 6H_2O$	74
JEFFSOL PC	∞	Nitrocellulose	>10
Toluene	∞	Nylon, Type 8 molding powder	>10(130°C)
Tricresyl phosphate	∞	Polyacrylonitrile	>10
Water	∞	Polyoxyethylene glycols	100
Acetylene	0.6	Rosin, dibasic acid modified	>10(205°C)
Alkyd resin, long oil-nonoxidizing	>10(160°C)	Sulfur dioxide	26
Camphor, USP	55-60	Triethylene glycol di-2-ethyl hexoate	5-7
Castor oil, USP	<1	Tri(2-ethylhexyl) phosphate	<2
Cellulose acetate	>10(100°C)	Urea	1.5
Cellulose acetate butyrate	>10(130°C)	Vinylidene chloride-acrylonitrile	10(110°C)
$CoCl_2 \cdot 6H_2O$	33	$ZnCl_2$	33
$Co(NO_3)_2 \cdot 6H_2O$	37		

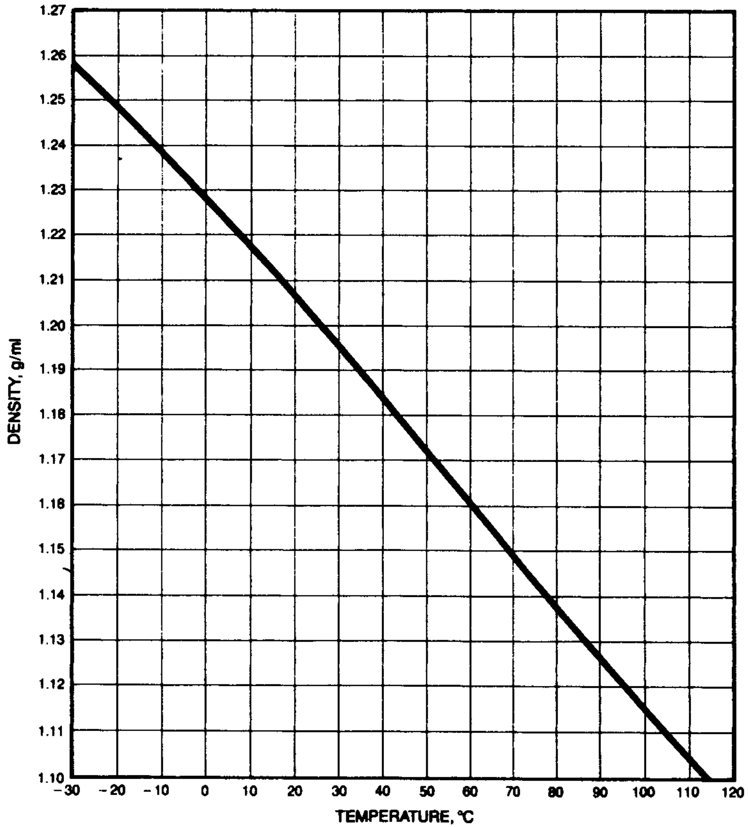
Density of JEFFSOL EC



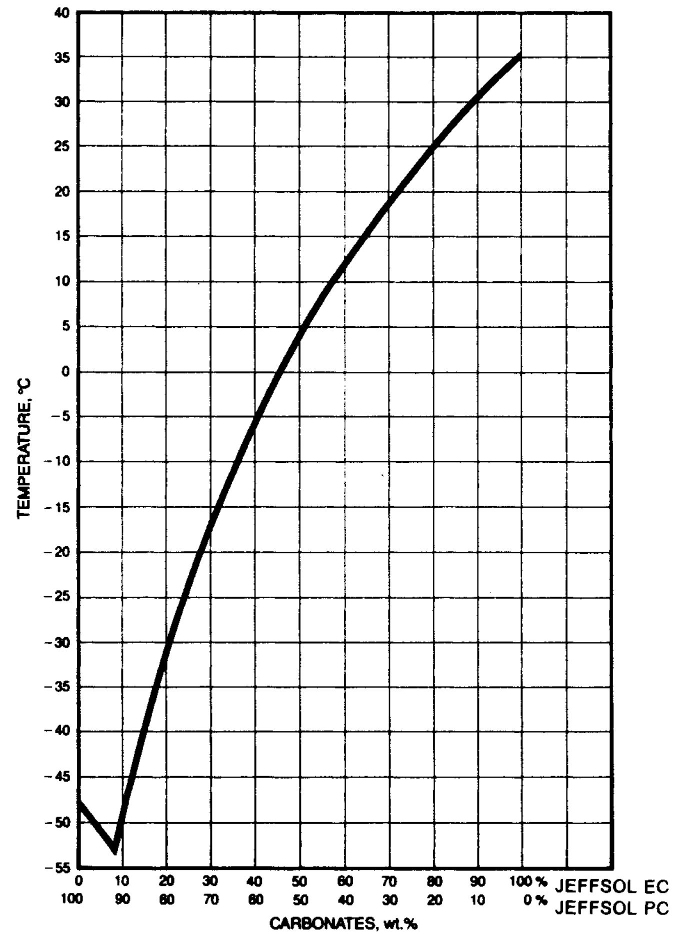
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Table 15.66: (continued)

Density of JEFFSOL PC



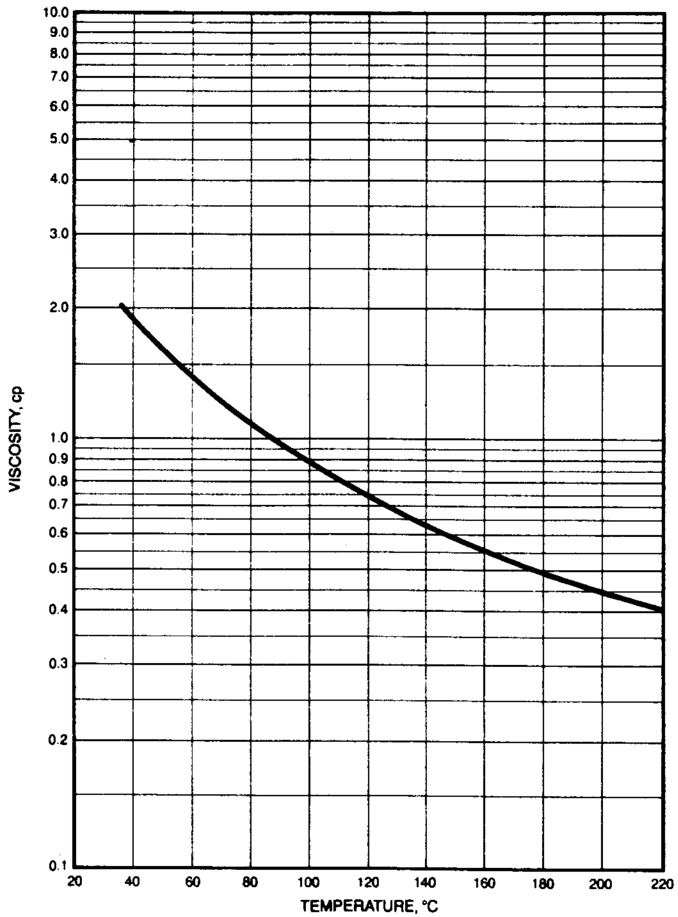
Freezing Points of JEFFSOL EC–JEFFSOL PC Mixtures



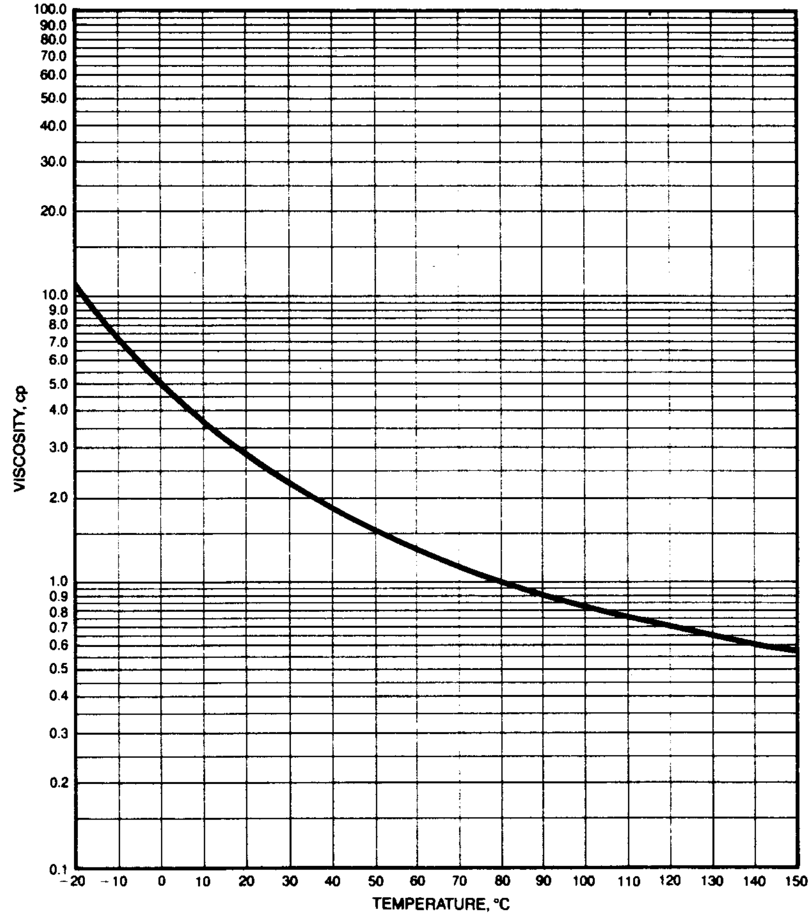
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Table 15.66: (continued)

Viscosity of JEFFSOL EC



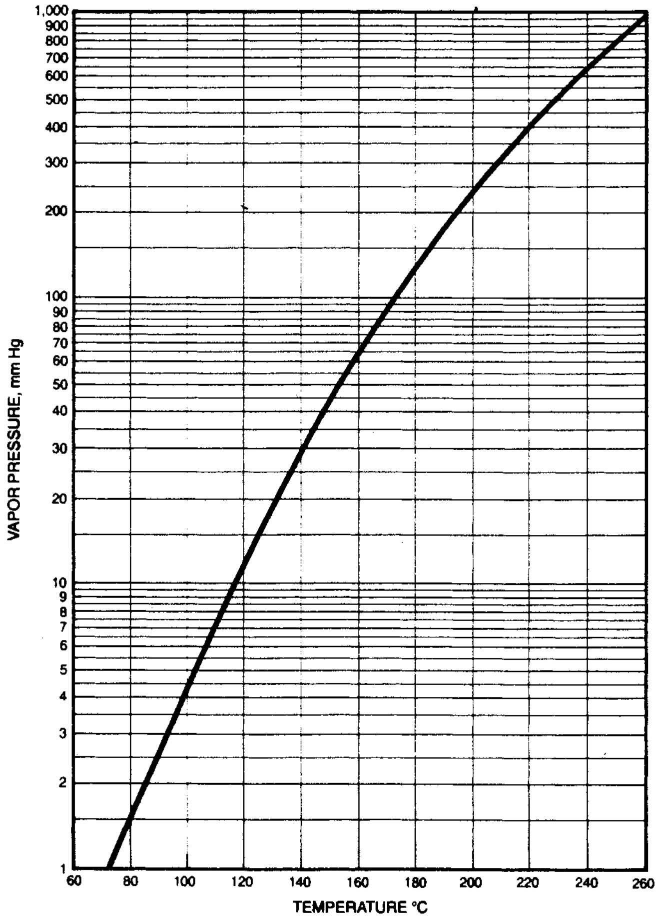
Viscosity of JEFFSOL PC



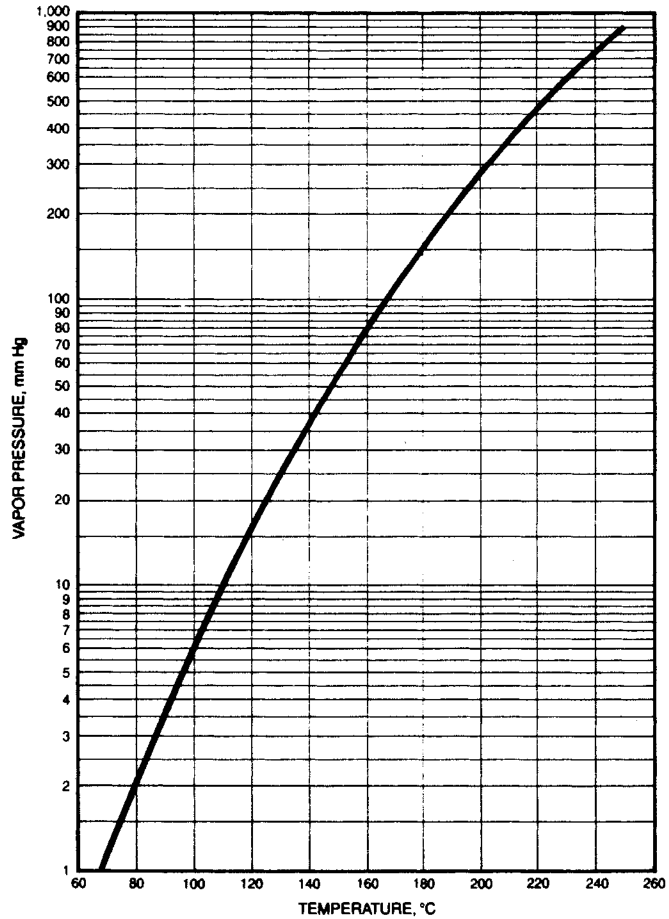
(continued)

Table 15.66: (continued)

Vapor Pressure of JEFFSOL EC



Vapor Pressure of JEFFSOL PC



PHTHALATES

Table 15.67: Alkyl Benzyl Phthalates *(75)*

SANTICIZER 261

Table A. Properties

Molecular Weight	368
• Acidity (meq/100 gm. max)	0.37
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	75
• Moisture (KF in Methanol) %, max.	0.15
Odor	Slight, characteristic
• Refractive Index (@ 25°C)	1.523 – 1.529
• Specific Gravity (25°/25°C)	1.065 – 1.074
Density (@ 25°C) ca. lbs./gal.	8.9
Pour Point (°C)	−45
Boiling Point @ 10mm Hg, °C	252
Vapor Pressure (mm Hg)	
@ 200°C	0.5
@ 250°C	9.7
Viscosity (Centistokes)	
@ 25°C	53
@ 98.9°C	4.2
Surface Tension @ 24°C (dynes/cm)	35.3
Thermal Expansion Coefficient @ 10° – 40°C (cc/cc/°C)	0.00059
Flash Point (C.O.C.) [°F.]	445
Solubility In Water @ 25°C, %	0.00003
Hydroxyl number	<3
CAS Number	68515-40-2

• Specification

Table B. Santicizer®261 – Properties of Acrylic Lacquers

Plasticizer (at 29%)	Hardness[1]	Weatherometer Gloss/ Reflectance		Fog[2] Value	Adhesion[3]	Solvent 5°C.	Craze[4] 10°C.	Water[5] Immers.
Santicizer® 160	F/H	Std.	Std.	37 SR	4	checked	checked	Std.
Santicizer 261	F/H	+	+	66 SR	6	checked	OK	Equiv.

1. Pencil Hardness – The film is harder than the top letter, softer than the bottom letter.
2. Specular Reflection (SR) or plate glass covers over breakers in which the plasticized films were heated for 1 hr. @ 110°C.
3. Cellophane tape method.
4. Coated panels conditioned at 5 and 10° C. – a drop of methyl ethyl ketone was applied and allowed to dry. Crazing determined by visual observation (with magnifying lens).
5. Panels immersed in water at 40°C. for 100 hours – rated by ASTM test D-714.

Table C. Santicizer®261 – Performance in PVC

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility, 24 hours at 87°C in carbon	2.1	2.1	2.3
Low-temperature flex, T_f °C	−7	−26	−40
Water extraction, 24 hours at 50°C	0.02	0.07	0.08
Kerosene extraction, 24 hours at 23°C	1.0	3.8	8.8
Shore "A" hardness, 10 second reading	89	71	54

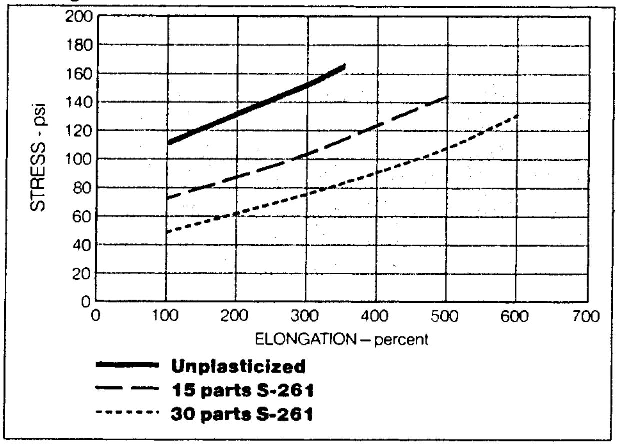
Table D. Santicizer®261 – Performance in Plastisol Formulation

Viscosity, poises Brookfield HAT #6 Spindle		
50 RPM		**65 PHR**
23°C	Initial	63
	7 Days	74
	28 Days	86
40°C	Initial	32
	7 Days	110
	28 Days	170
50°C	Initial	36
	7 Days	150
	28 Days	Gel
Severs	10 psi	160
	50 psi	230
	100 psi	180
Yield Value, dynes/cm²		28
Flow Index		3.6
Gel Temperature, °C		67
Fusion, Relative Temperature, °C		159

(continued)

Table 15.67: (continued)

Table E. Plasticizer Effect on Polysulfide Polymer Strength



Data Courtesy of Morton Thiokol, Inc.

Table F. Polysulfide Strength at Break as a Function of Plasticizer Level

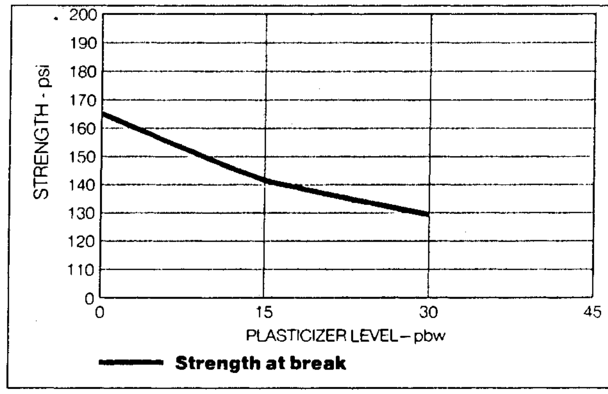
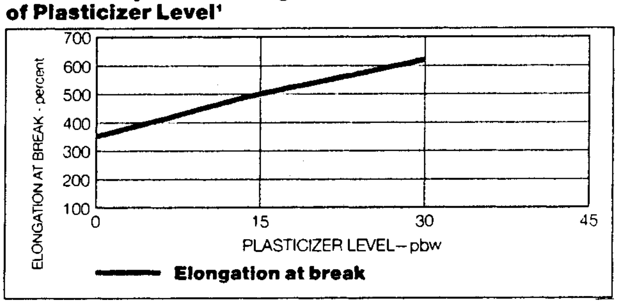


Table G. Polysulfide Elongation at Break as a Function of Plasticizer Level[1]

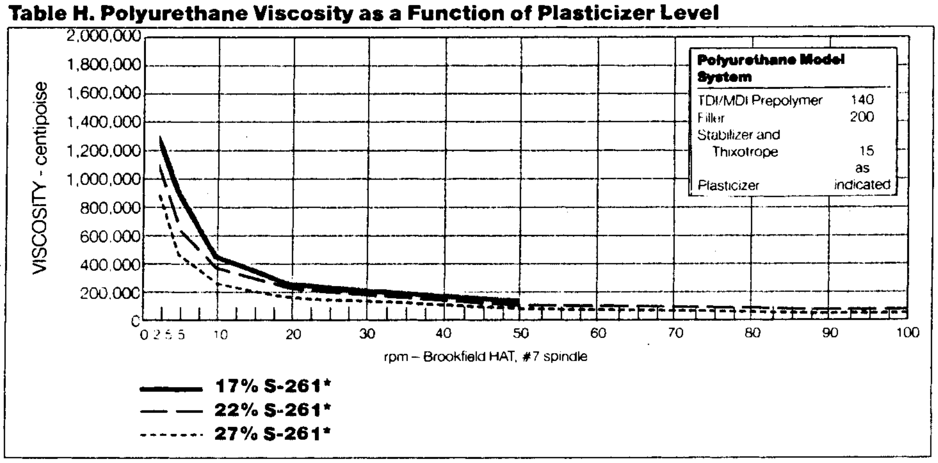


[1] Plasticizer Effect on Calcium Carbonate Filled Polysulfide Composition. (Cast sheets cured 7 days at 70-72°F and 44-48% Relative Humidity.)

Formulation (parts by weight-pbw)

Part A	
LP-32 Polymer	100
Ultrafine precipitated $CaCO_3$	50
Stearic Acid	0.5
Sulfur	0.1
Santicizer® 261	0-30
Part B	
MnO_2	7.5
Santicizer 278	7.5

Table H. Polyurethane Viscosity as a Function of Plasticizer Level



*Plasticizer as % of total system.

(continued)

Table 15.67: (continued)

SANTICIZER 278

Table A. Properties

Molecular Weight	455
• Acidity (meq/100 gm. max)	0.37
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	175
• Moisture (KF in Methanol) % max.	0.15
Odor	Slight, characteristic
• Refractive Index (@25°C)	1.516 – 1.520
• Specific Gravity (25°/25°C)	1.093 – 1.100
Density (@ 25°C) ca. lbs./gal.	9.1
Boiling Point @ 10mm Hg, °C	243
Vapor Pressure (mm Hg)	
@ 200°C	0.5
@ 250°C	15
Viscosity (Centistokes)	
@ 0°C	ca. 10,000
@ 25°C	860
@ 98.9°C	11.5
Surface Tension @ 25°C (dynes/cm)	34.8
Thermal Expansion Coefficient @ 10° – 40°C (cc/cc/°C)	0.00073
Flash Point (C.O.C.) [°F.]	440
Fire Point (C.O.C.) [°F.]	535
Solubility In Water @ 25°C, %	Practically insoluble
CAS Number	16883-83-3

• Specification

Table B. Santicizer® 278—Performance in PVC (40 Mil Sheet)

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility (% Lost) (Activated Carbon 24 hours at 87°C)	0.7	0.7	0.7
Low-temperature Flex, Tf °C	+ 19	+ 2	− 14
Water immersion (24 hours at 50°C)			
% soluble matter lost	0.01	0.02	0.04
% water absorbed	0.28	0.33	0.36
Kerosene extraction (24 hours at 23°C) (% plasticizer lost)	0.3	0.5	1.3
Shore "A" Hardness, 10 second reading	97	85	65
Migration, Linde Silica:			
1 day	0.0	0.0	0.0
3 days	0.04	0.08	0.3
7 days	0.05	0.14	0.5
Tensile, p.s.i.	3180	2600	2030
Elongation, %	258	340	410
Modulus @ 100% Elongation	3140	1850	840
Heat Stability	Good	Good	Good
Migration Resistance to Nitrocellulose	Good	Good	Good
Fluxing Rate	Good	Good	Good

Table C. Santicizer® 278—Performance in Plastisol Formulation

Viscosity, poises Brookfield HAT Spindle **50 RPM**		**65 PHR**
23°C	Initial	1370
	7 Days	1420
	28 Days	1400
40°C	Initial	380
	7 Days	560
	28 Days	640
50°C	Initial	160
	7 Days	600
	28 Days	900
Severs	10 psi	3400
	50 psi	3900
	100 psi	1900
Yield value, dynes/cm^2		0
Flow Index		2.8
Gel Temperature, °C		79
Fusion, Relative Temperature, °C		156

(continued)

Table 15.67: (continued)

Table D. Use of Santicizer® 278 to Replace Polymeric Plasticizers

	Santicizer® 278	High M.W. Polyester
Shore "A" Hardness, 10 second reading	84	77
Volatility, % Plasticizer Lost 6 days @ 87°C in carbon	3.9	2.0
Tf. °C	-1	-18
Extraction, % Plasticizer Lost		
5% Caustic, 96 hours @ 23°C	0.1	0.6
1% Ivory Soap, 96 hours @ 50°C	3.0	9.2
Hexane, 4 hours @ 23°C	1.6	1.3
Hexane, 24 hours @ 23°C	3.2	2.7
Humidity Compatibility 100% R.H.		
Days to exude @ 60°C	Pass*	70
Days to exude @ 80°C	Pass*	18
Water Sensitivity, 24 hours @ 50°C		
% Soluble Matter Lost	0.05	0.08
% Absorption	0.69	1.28
Viscosity, stokes @ 23°C Gardner Bubble	7	47
Fusion, via Fisher-Johns Clear Point, °C	115	153

Formulation

PVC	100
Plasticizer	67
Mark WS	1

*Test terminated at 126 days (18 weeks) with no exudation.

Table E. Adhesive Migration Resistance

	Peel Strength lbs./in.[1]	Failure Mode
Emulsion Type PSA		
Santicizer® 278	6.2	Cohesive
High M.W. Polyester	5.9	Cohesive
Solution Type PSA		
Santicizer 278	5.0	Cohesive
High M.W. Polyester	4.2	Cohesive

[1]24 Hours @ Room Temperature

Formulation

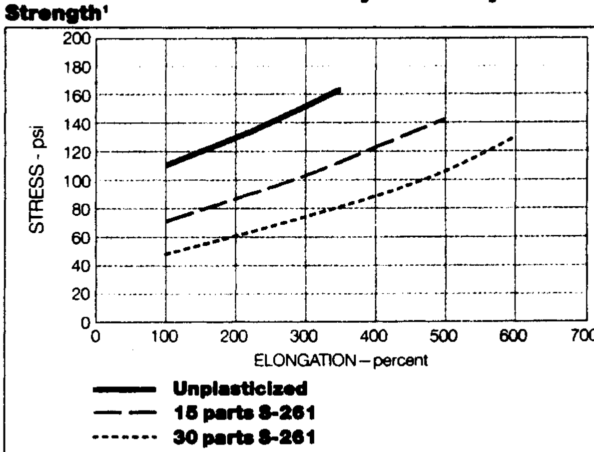
PVC	100
Plasticizer	25
Processing Aid	5
Stabilizer	3
TiO_2	10

Table F. Performance of Santicizer® 278 in Moisture Cured Urethane Sealants[1]

	Plasticizer Concentration 17%	22%	27%
Modulus, psi			
200%	135	130	125
400%	200	190	190
% Elongation	540	490	490
Tensile Strength, psi	240	205	210
Shore A Hardness @ 5 sec.	29	29	30

[1]Cured 2 Weeks at 25°C/50% Relative Humidity

Table G. Plasticizer Effect on Polysulfide Polymer Strength[1]



Formulation (parts by weight - pbw)

Part A	
LP-32 Polymer	100
Ultrafine precipitated $CaCO_3$	50
Stearic acid	0.5
Sulfur	0.1
Santicizer® 261	0-30
Part B	
MnO_2	7.5
Santicizer 278	7.5

[1]Plasticizer Effect on Calcium Carbonate Filled Polysulfide Composition. (Cast sheets cured 7 days at 70-72°F and 44-48% Relative Humidity.)

Data courtesy of Morton Thiokol Inc.

Table 15.68: Butyl Benzyl Phthalate *(75)*

SANTICIZER 160

Table A. Properties

Molecular Weight	312
• Acidity (meq/100 gm. max)	0.37
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	40
• Moisture (KF in Methanol) %, max.	0.15
• Odor	Slight, characteristic
• Refractive Index (@25°C)	1.535 – 1.540
• Specific Gravity (25°/25°C)	1.115 – 1.123
Density (@ 25°C) ca. lbs./gal.	9.3
Hydroxyl No.	<1
Crystallizing Point (°C)	< –35
Pour Point (°C)	–45
Boiling Point @ 10mm Hg, °C	240
Vapor Pressure (mm Hg)	
@ 150°C	0.16
@ 200°C	1.9
@ 250°C	14.4
Viscosity (Centistokes)	
@ 0°C	230
@ 25°C	39.5
@ 98.9°C	3.42
Surface Tension @ 25°C (dynes/cm)	39.9
Thermal Expansion Coefficient @ 10° – 40°C (cc/cc/°C)	0.00069
Flash Point (C.O.C.) [°F.]	390
Fire Point (C.O.C.) [°F.]	450
Solubility In Water @ 25°C,%	0.0003
CAS Number	85-68-7

• Specification

Table B. Performance of Santicizer® 160 in PVC (40 Mil Sheet)

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility (% Lost) (Activated Carbon; 24 hours at 87°C)	7.0	7.7	8.1
Low-Temperature Flex, Tf °C	–3.8	–24	–39
Water immersion (24 hours at 23°C)			
% soluble matter lost	0.06	0.07	0.08
% water absorbed	0.35	0.30	0.43
Kerosene extraction (24 hours at 23°C) (% plasticizer lost)	1.0	3.4	8.2
Shore "A" Hardness, 10 second reading	86	68	52
Migration, Linde Silica:			
1 day	0.2	1.2	4.0
3 days	0.4	2.5	7.8
7 days	0.7	4.1	11.4
Tensile, p.s.i., ASTM D-412	3090	2270	1420
Elongation, %, ASTM D-412	350	450	460
Modulus @ 100% Elongation, ASTM D-412	1960	1000	510

(continued)

Table 15.68: (continued)

Table C. Effect of Additive Use of Santicizer® 160 with GPP Based Plastisols on Gel and Fusion Properties

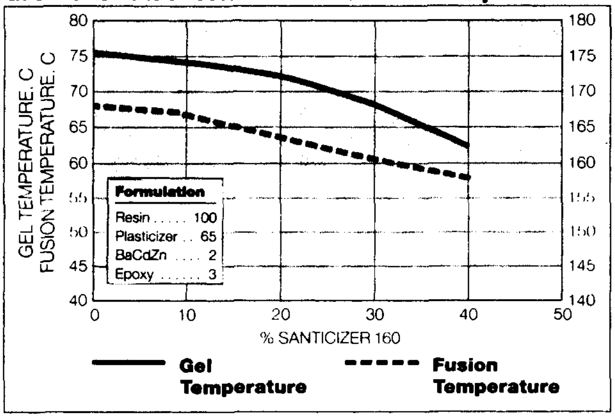
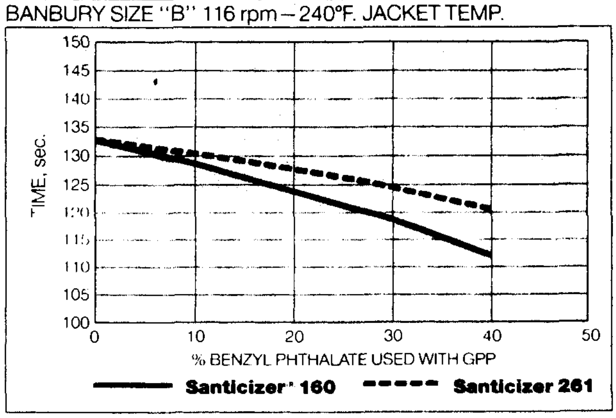


Table D. Effect of Benzyl Phthalates on Fusion

BANBURY SIZE "B" 116 rpm – 240°F. JACKET TEMP.



PVAc ADHESIVE APPLICATION DATA

Table E. Performance of Plasticizers in Acrylic Automotive Lacquers

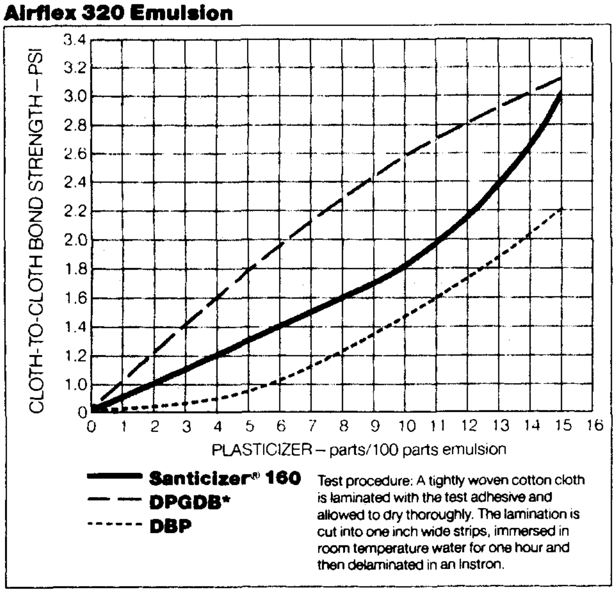
20% Plasticizer Concentration

Plasticizer	Humidity[1] Stability	Volatility[2]	Sward Hardness
Santicizer® 160	1	46	44
Dipropylene Glycol Dibenzoate	**8**	51	52
DBP	1	>**70**	46

[1]Visual Rating 1-10; 1 = best; 10 = worst

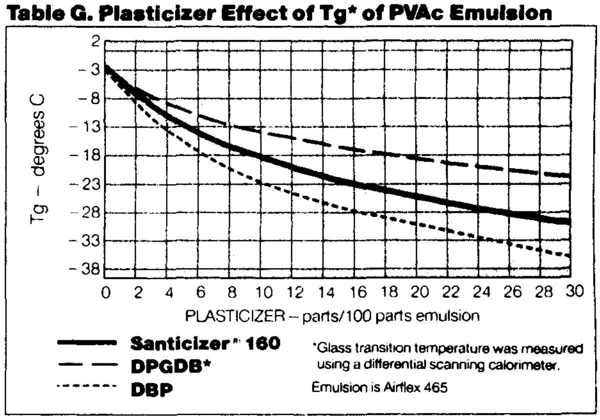
[2]% Plasticizer lost @ 170°F 3 mil coating

Table F. Effect of Plasticizers on Water Resistance of Airflex 320 Emulsion



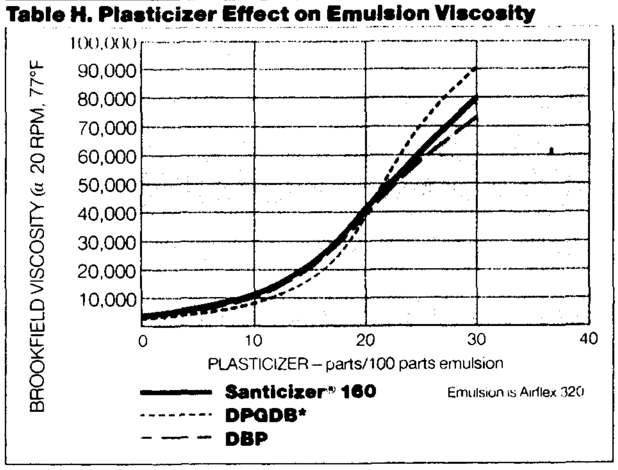
Data Courtesy Air Products and Chemicals Inc.

Table G. Plasticizer Effect of Tg* of PVAc Emulsion



Data Courtesy Air Products and Chemicals Inc.

Table H. Plasticizer Effect on Emulsion Viscosity



Data Courtesy Air Products and Chemicals Inc.

*Dipropylene Glycol Dibenzoate

Table 15.69: Dibutyl Phthalate *(75)*

DBP

Table A. Properties

Molecular Weight	278
Acidity (meq/100 gm.)	0.12
Appearance	Clear, oily liquid
Color (APHA) max.	20
Moisture (KF in Methanol) %	0.15
Odor	Slight, characteristic
Refractive Index (@25°C)	1.4895 – 1.4915
Specific Gravity (25°/25°C)	1.044 – 1.048
Density (@ 25°C) ca. lbs./gal.	8.72
Crystallizing Point (°C)	< – 35
Pour Point (°C)	– 40
Boiling Point @ 10mm Hg, °C	192
Vapor Pressure (mm Hg)	
@ 150°C	0.8
@ 200°C	14
@ 250°C	100
Viscosity (Centistokes)	
@ 0°C	55.0
@ 25°C	15.6
@ 98.9°C	2.4
Surface Tension @ 30°C (dynes/cm)	35
Thermal Expansion	0.00078
Coefficient @ 10° – 40°C (cc/cc/°C)	
Flash Point (C.O.C.) [°F.]	340
Fire Point (C.O.C.) [°F.]	395
Solubility In Water @ 30°C, %	0.001
General Solubility	Soluble in all common organic solvents and oils
CAS Number	84-74-2

Table B. Dibutyl Phthalate—Evaluation in Polyvinyl Acetate Adhesives

Formulation: Gelva® S-55 90% resin
Plasticizer 10%

Room Temperature Viscosity, cps. (Brookfield LVT #3 Spindle, 30 rpm)	**Dibutyl Phthalate**	**Santicizer® 160**
Initial	2070	2000
1 Day	2080	1900
1 Week	2480	2170
2 Weeks	2520	2490
4 Weeks	4080	3970
Wet Tack (sec.)	15	14
Open Time (min.:sec.)	3:45	3:30
Elongation, %	385	335
100% Modulus, psi	300	430
Tensile Strength, psi	690	920

Table 15.70: Di-2-Ethylhexyl Phthalate (Dioctyl Phthalate) *(75)*

DOP

Table A. Properties

Molecular Weight	391
Acidity (meq/100 gm. max)	0.12
Appearance	Clear, oily liquid
Color (APHA)	25
Moisture (KF in Methanol) %	0.10
Odor	Slight, characteristic
Refractive Index (@25°C)	1.4845 – 1.4858
Specific Gravity (25°/25°C)	0.980 – 0.985
Density (@ 25°C) ca. lbs./gal.	8.18
Crystallizing Point (°C)	–55 (very stiff gel)
Pour Point (°C)	–47
Boiling Point @ 10mm Hg, °C	236
Vapor Pressure (mm Hg)	
@ 200°C	1.2
@ 250°C	18
Viscosity (Centistokes)	
@ 0°C	348.0
@ 25°C	58.0
@ 98.9°C	4.3
Surface Tension @ 25°C (dynes/cm)	33
Thermal Expansion Coefficient @ 10° – 40°C (cc/cc/°C)	0.00074
Flash Point (C.O.C.) [°F.]	425
Fire Point (C.O.C.) [°F.]	480
Solubility In Water @ 25°C,%	<0.005
General Solubility	Miscible with most common solvents and with most primary and secondary plasticizers for polyvinyl chloride
CAS Number	117-81-7

Table B. Performance in PVC (40 Mil Sheet)

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility (% Lost) (Activated Carbon)	4.2	4.0	4.0
Low-temperature Flex, Tf °C	–17	–39	–55
Water immersion (24 hours):			
% soluble matter lost	0.01	0.03	0.04
% water absorbed	0.22	0.25	0.27
Kerosene extraction (% plasticizer lost)	8.3	44	>70
Shore "A" Hardness	87	70	53
Tensile, p.s.i.	2910	2230	1390
Elongation, %	360	460	480
Modulus @ 100% Elongation, psi	1950	990	500
Flammability, Limiting O_2 Index *	23.1	21.8	20.3

*The Oxygen Index Test results are not intended to reflect performance of these or any other materials under actual fire conditions. Each user should determine independently whether potential fire hazards are associated with the finished product, and whether DOP is suitable for the particular use.

Table C. DOP Performance in Plastisol Formulation

Viscosity, poises Brookfield HAT #6 Spindle

50 RPM		65 PHR
23°C	Initial	36
	7 Days	65
	28 Days	82
40°C	Initial	25
	7 Days	94
	28 Days	102
50°C	Initial	28
	7 Days	210
	28 Days	260
Severs	10 psi	58
	50 psi	50
	100 psi	41
Yield value, dynes/cm^2		0
Flow Index		1.4
Gel Temperature, °C		75
Fusion, Relative Temperature, °C		167
*Air-Release Rate		Moderate
*Resilience, steel ball, inches		4.5

*Efficiency Conc. Adj. to "60" Shore A hardness

PHOSPHATES

Table 15.71: t-Butylphenyl Diphenyl Phosphate *(75)*

SANTICIZER 154

Table A. Properties

Molecular Weight (avg.)	371
Phosphorus, %	8.4 (Calc)
• Acidity (meq/100g.) max.	0.20
• Appearance	Clear, mobile liquid
• Color (APHA) [max.]	100
• Moisture, % max.	0.15
• Odor	Essentially odorless
Refractive Index @25°C	1.5535 – 1.5565
Sp. Grav. 25°C/25°C	1.175 – 1.185
Density @ 25°C lbs./gal.	9.8
Crystallizing Point (°C)	< –20
Pour Point (°C)	–25
Boiling Point @ 10mm Hg, °C	258
Vapor Pressure	
@ 200°C	1.0
@ 250°C	7.4
@ 300°C	41

Viscosity (Centistokes)	
@ 0°C	475
@ 25°C	58
@ 100°C	4.1
Flash Point (COC, °F.)	505
Fire Point (COC °F.)	590
Sol. in Water @ 25°C	<0.001%
Coefficient of Thermal Expansion @ 10-40°C (cc/cc/°C)	0.000703
Surface Tension (Dynes/cm)	38.6 @ 23°C
CAS Number	56803-37-3

• Specification

Table B. Santicizer® 154 Comparative Performance in Plasticized, Flame-retarded Compounds

VINYL FILM

Physical Properties in PVC, 67 PHR

Plasticizer	T_f,°C	Volatility % Lost	Shore Hardness "A"	Water Ext/Abs	Kerosene Extraction
Santicizer® 154	–10.5	3.1	78	.08/.49	1.4
Tricresyl phosphate	–14.2	1.3	72	.03/.26	2.4
Isopropylated triphenyl phosphate	–14.6	2.9	77	.07/.40	1.9
Blend (70/30) of Santicizer 154/148	–17.2	3.0	75	.07/.47	3.0

Flame-retardant Properties

Plasticizer	Flame Spread (Monsanto Two-foot Tunnel Test)*	% Light Transmission	Oxygen Index
Santicizer® 154	3.0	9	29.5
Tricresyl phosphate	3.0	7	29.3
Isopropylated triphenyl phosphate	3.0	10	29.3
Blend (70/30) of Santicizer 154/148	3.3	15	28.7

Formulation	PHR
Geon[1] 102 vinyl resin	100
Plasticizer (as indicated)	50
Drapex[2] 10.4 epoxidized linseed oil	3
Mark[2] WS stabilizer	2
Atomite[3] calcium carbonate filler	30

NITRILE RUBBER SHEET

Physical Properties

Plasticizer	Monsanto Rehometer (350°F, 100 CPM, 1° arc) T 90% (min.)	100% Modulus	Tensile (PSI)	Elongation %
Santicizer® 154	5.5	610	995	345
Isopropylated triphenyl phosphate	5.6	570	875	330
Santicizer 148	6.0	490	815	385

Flame-retardant Properties

Plasticizer	Vertical Burn Test (UL 94)*	Oxygen Index*
Santicizer® 154	V-O	42.0
Isopropylated triphenyl phosphate	V-O	41.5
Santicizer 148	V-O	39.9

Formulation	PHR
Paracril[4] OZO nitrile PVC polyblend	75
Pliovic[5] M50 vinyl chloride resin	25
Hydral[6] 710 alumina hydrate	100
Hard Dixie clay	25
MagCarb[7]L	5
Thermogard[8] antimony trioxide	4
Dyphos[9] stabilizer	3
Stearic acid	1
Drapex[2] 10.4 epoxidized linseed oil	3
Zinc oxide	3
Spider[10] sulfur	1.5
Thiofide® MBTS accelerator	1.5
Thiurad® TMTD accelerator	0.2
Plasticizer (as indicated)	35

*The Oxygen Index, UL 94, and the Two-foot Tunnel Test results are not intended to reflect performance of these or any other materials under actual fire conditions. Each user should determine independently whether potential fire hazards are associated with the finished product and whether Santicizer 154 is suitable for the particular use.

Trademarks of
(1) B. F. Goodrich Inc. (2) Argus Chemical Corp.
(3) Thompson Weinman's Co. (4) Uniroyal Inc.
(5) Goodyear Tire & Rubber Co.
(6) Aluminum Company of America
(7) Merck & Co., Inc. (8) M & T Chemicals Inc.
(9) NL Industries Inc. (10) Stauffer Chemical Co.

Table C. Autoignition Temperature

(ASTM D-2155-66)

Fluid	A.I.T., °F
Santicizer® 154	1,050
Butylated triphenyl phosphate	1,025
Isopropylated triphenyl phosphate	1,010
Hydrocarbon (typical)	700 – 750

Table 15.72: 2-Ethylhexyl Diphenyl Phosphate *(75)*

SANTICIZER 141

Table A. Properties

Molecular Weight	362
Phosphorus, %	8.6 (Calc)
• Acidity (meq/100 gm. max)	0.20
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	40
• Moisture (KF in Methanol) %, max.	0.10
• Odor	Essentially odorless
• Refractive Index (@25°C)	1.508 – 1.511
• Specific Gravity (25°/25°C)	1.0880 – 1.093
Density (@ 25°C) ca. lbs./gal.	9.1
Pour Point (°C)	–54
Boiling Point @ 10mm Hg, °C	239 (decomposes)
Vapor Pressure	
@ 150°C	0.2
@ 200°C	1.6
Viscosity (Centistokes)	
@ 0°C	61.0
@ 25°C	16.4
@ 98.9°C	2.5
Surface Tension @ 22°C (dynes/cm)	33.4
Flash Point (C.O.C.) [°F.]	435
Fire Point (C.O.C.) [°F.]	460
Solubility In Water @ 25°C, %	0.002
CAS Number	1241-94-7

• Specification

Table B. Flow Index and Fusion Points of Various Plasticizers

Plasticizer	Gel Point, °C	Fusion Point, °C	Flow Index*
Santicizer® 160	89	148	9.5
CDP	100	143	13.0
Santicizer 141	**105**	**151**	**2.4**
DOP	127	167	1.4
7-9-11 Phthalate	128	172	1.2
DOA	139	175	0.6
Santicizer 97	143	177	1.0

*Ratio of Severs visc. (50 psi) to Brookfield visc. (50 RPM).

Table C. Plastisol Viscosity Stability (Formulated With 100 PHR Geon® 121)

Plasticizer	PHR	Temp., °C	Brookfield Viscosity—Poises RPM	Initial	1 Day	7 Days	28 Days
DOP	65	23	5	64	98	93	109
			50	58	86	80	96
		40	5	57	80	115	147
			50	40	59	86	109
Santicizer® 141	65	23	5	94	147	208	259
			50	56	84	112	154
		40	5	128	896	7,040	Gelled
			50	71	368	2,509	Gelled
DOP and Santicizer 141	60/5	23	5	64	70	86	112
			50	54	59	67	94
		40	5	48	104	147	224
			50	34	66	101	133
DOP and Santicizer 141	50/15	23	5	96	112	128	173
			50	62	66	74	100
		40	5	64	186	352	480
			50	42	93	162	216

Severs Viscosity Data

	DOP (65 PHR)	Santicizer 141 (65 PHR)	DOP and Santicizer 141 (60/5 PHR)	DOP and Santicizer 141 (50/15 PHR)
10 psi	84*	58	86	77
50 psi	80	64	81	76
100 psi	62	58	60	54

(continued)

Table 15.72: (continued)

Table D. Effect of Plasticizers and Thickness on Weatherability of PVC Film

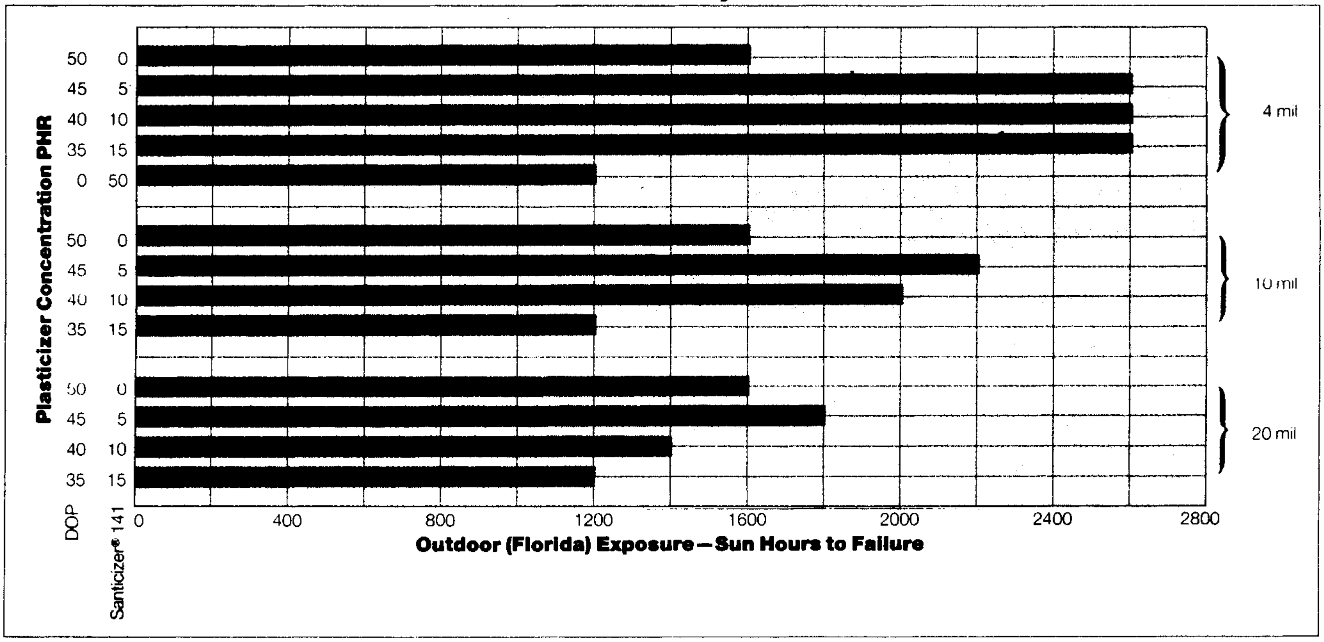
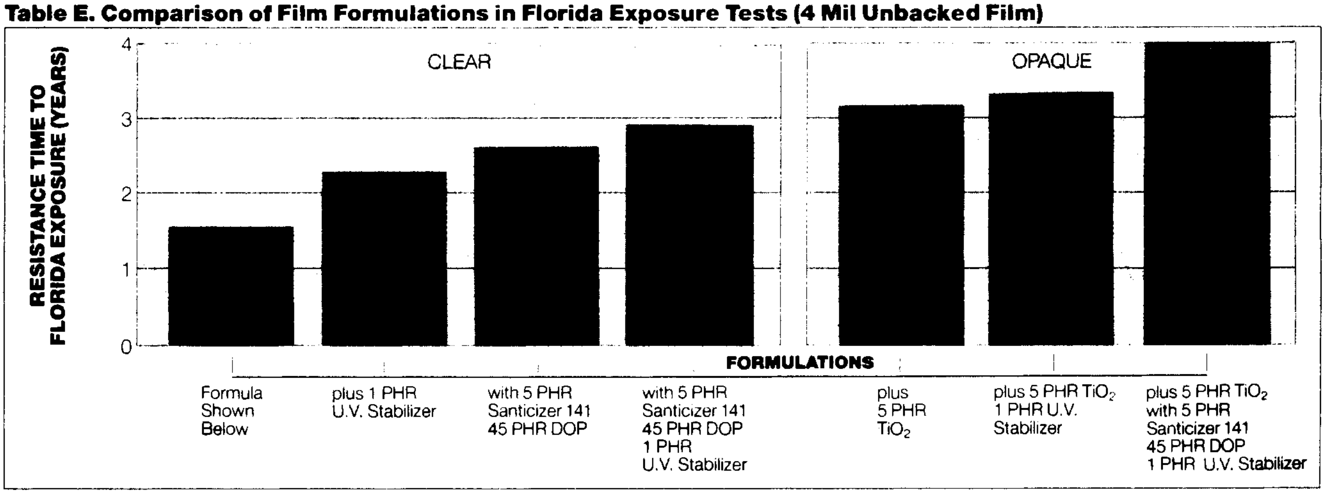


Table E. Comparison of Film Formulations in Florida Exposure Tests (4 Mil Unbacked Film)



Formulation	
PVC	100
DOP	50
Epoxidized soya oil	3
Liquid Ba/Cd	2
Liquid Zn	0.25
Stearic Acid	0.5
U.V. Stabilizer:	2-Hydroxy-4-Methoxy Benzophenone

(continued)

Table 15.72: (continued)

Table F. Santicizer® 141—Performance in PVC (40 Mil Sheet)

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility (% Plasticizer Lost) (Activated Carbon 24 hours at 87°C)	6.8	7.4	8.4
Low-temperature Flex, Tf°C (Clash-Berg Method)	−17	−39	−58
Water immersion (24 hours at 50°C)			
% soluble matter lost	0.02	0.06	0.25
% water absorbed	0.24	0.36	0.50
Kerosene extraction (24 hours at 23°C) (% plasticizer lost)	3.0	7.3	24
Shore "A" Hardness, 10 second reading	84	68	50
Migration, Linde Silica:			
1 day	0.3	1.5	4.2
3 days	1.2	4.6	12.3
7 days	2.1	9.0	22.4
Tensile, p.s.i.	2930	2210	1310
Elongation, %	320	440	510
Modulus @ 100% Elongation	1810	820	450
Flammability (Limiting O_2 Index)*	27.0	25.4	24.9
Heat Stability	Fair	Fair	Fair
Migration Resistance to Nitrocellulose	Poor	Poor	Poor
Fluxing Rate	Excellent	Excellent	Excellent

*The Oxygen Index Test results are not intended to reflect performance of these or any other materials under actual fire conditions. Each user should determine independently whether potential fire hazards are associated with the finished product and whether Santicizer 141 is suitable for the particular use.

Table G. Santicizer® 141—Performance in Plastisol Formulation

Viscosity, poises Brookfield HAT #6 Spindle 50 PRM		65 PHR
23°C	Initial	24
	7 Days	59
	28 Days	88
40°C	Initial	26
	7 Days	640
	28 Days	Gel
50°C	Initial	170
	7 Days	Gel
	28 Days	Gel
Severs	10 psi	47
	50 psi	58
	100 psi	54
Yield value, dynes/cm^2		12
Flow Index		2.4
Gel Temperature, °C		64
Fusion, Relative Temperature, °C		151
*Air-release Rate		Moderate
*Resilience, steel ball, inches		5.8

*Efficiency Conc. Adj. to "60" Shore A Hardness

Table 15.73: Isodecyl Diphenyl Phosphate *(75)*

SANTICIZER 148

Table A. Properties

Molecular Weight	390
Phosphorus, %	7.9 (Calc)
• Acidity (meq/100 gm. max)	0.20
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	100
• Moisture (KF in Methanol) %, max.	0.10
• Odor	Essentially odorless
• Refractive Index (@25°C)	1.504 – 1.510
• Specific Gravity (25°/25°C)	1.069 – 1.079
Density (@ 25°C) ca. lbs./gal.	8.94
Crystallizing Point (°C)	< –35
Pour Point (°C)	< –50
Boiling Point @ 10mm Hg, °C	245 (decomposes)
Vapor Pressure (mm Hg)	
@ 150°C	<0.1
@ 200°C	0.5
Viscosity (Centistokes)	
@ 0°C	95
@ 25°C	22.5
@ 98.9°C	3.0
Flash Point (C.O.C.) [°F.]	465
Fire Point (C.O.C.) [°F.]	500
Thermal Expansion Coefficient @ 10° – 40°C (cc/cc/°C)	0.00071
Solubility In Water @ 25°C,%	<0.0008
CAS Number	29761-21-5

• Specification

Table B. Effect of Type of Filler

(25% Phosphate Ester as Shown Blended With 711 Phthalate

	Monsanto Two-foot Tunnel* Test Inches of Flame Spread		Oxygen Index % O_2 to Sustain Burning	
30 PHR Atomite	**No Sb_2O_3**	**4 PHR Sb_2O_3**	**No Sb_2O_3**	**4 PHR Sb_2O_3**
Control (No phosphate ester)	11.9	6.7	23.2	26.7
Triarylphosphate**	7.4	6.8	25.6	27.6
Santicizer® 148	8.6	6.8	24.4	26.8
30 PHR Hydral* 710**				
Triarylphosphate**	3.3	2.9	29.4	30.3
Santicizer 148	4.3	3.3	28.6	29.8
30 PHR Atomite/Magcarb** L(2/1)**				
Triarylphosphate**	6.6	4.4	26.1	28.9
Santicizer 148	4.7	3.6	24.7	28.2

*For a description of the Two-foot Tunnel and its operation, see "The Use of a Small Flame Tunnel For Evaluating Fire Hazard" by H.L. Vandersall, Journal of Paint Technology, Vol. 39, No. 11, August 1967.

**Isopropylated triphenylphosphate.

***Trademark of Aluminum Company of America.

****Trademark of Merck & Co. Inc. For details see Monsanto U.S. Pat. 3,869,420.

Table C. Vertical Burn Performance of Antimony Trioxide Vs. All Phosphate Ester (50 PHR) Plasticizer

	Federal Specification CCC-T-191b, Method 5903		
	Char Length (in.)	**After-flame (sec.)**	**After-glow**
711 Phthalate + 4 PHR Sb_2O_3	3.2	9.0	0
Triarylphosphate*	2.5	1.0	0
Santicizer® 148	2.9	1.0	0

*Isopropylated triphenylphosphate.

(continued)

Table 15.73: (continued)

Table D. Comparison of Smoke Generation (50 PHR Plasticizer; Atomite Filler) Monsanto Two-foot Tunnel Results

	% Light Transmission at Maximum Smoke Density*
(a) 711 Phthalate (control)	12
(b) 50 PHR Phosphate Ester	
Triarylphosphate**	4
Santicizer® 148	29
(c) 25% Phosphate Ester blend with 711 Phthalate	
Triarylphosphate**	10
Santicizer 148	25

*Monsanto Two-foot Tunnel (as used for plastic) equipped with smoke box.
**Isopropylated triphenylphosphate.

Table E. Comparison of Smoke Generation (50 PHR Plasticizer; Atomite Filler) NBS Smoke Chamber*

	Specific Optical Density at Maximum Smoke Density in Chamber Dm Corrected		
	Flaming	Smoldering	Average
(a) 711 Phthalate (control) (50 PHR)	165	194	180
(b) 50 PHR Phosphate Ester			
Triarylphosphate**	346	209	278
Santicizer® 148	173	94	139
(c) 25% Phosphate Ester Blend with 711 Phthalate			
Triarylphosphate**	235	209	222
Santicizer 148	177	153	165

*See N.B.S. Technical Note 708: ASTM E-662
**Isopropylated triphenylphosphate.

Table F. Santicizer® 148—Performance in PVC Fire Retardant Plastisol Formulation

Brookfield HAT #6 Spindle 50 rpm		65 PHR
Viscosity Poises	**Initial**	**25**
@ **23°C**	1 Day	53
	7 Days	74
	Initial	24
@ **40°C**	1 Day	185
	7 Days	Gel

Table G. Santicizer® 148—Performance in PVC (40 Mil Sheet)

	(30%) 43 PHR	(40%) 67 PHR	(50%) 100 PHR
Volatility (% Plasticizer Lost) (Activated Carbon 24 hours at 87°C)	2.9	2.8	3.1
Low-temperature Flex, Tf°C (Clash-Berg Method)	−13	−34	−50
Water Immersion (24 hours at 50°C)			
Soluble Matter Lost, %	0.05	0.06	0.16
Water Absorbed %	0.33	0.41	0.53
Kerosene Extraction (% Plasticizer Lost 24 hours at 23°C)	1.7	6.4	14.6
Shore "A" Hardness, 10 second reading	83	69	52
Tensile, p.s.i.	2930	2210	1380
Ultimate Elongation %	370	460	500
Modulus @ 100% Elongation	1940	980	490
Heat Stability	Fair	Fair	Fair
Fluxing Rate	Excellent	Excellent	Excellent
*Flammability (Limiting O_2 Index)	26.9	25.1	24.7
Smoke Generation	Low	Low	Low

*For formulation, see Section III, Performance in PVC.

*The Oxygen Index Test results are not intended to reflect performance of these or any other materials under actual fire conditions. Each user should determine independently whether potential fire hazards are associated with the finished product and whether Santicizer 148 is suitable for the particular use.

Table 15.74: Emulsifiable Triaryl Phosphate *(76)*

Reofos 1884
Emulsifiable triaryl phosphate

Introduction

Reofos 1884 is a water-dispersible phosphate ester product which combines the excellent flame retardance of triaryl phosphates with convenient dispersibility in aqueous systems.

Reofos 1884 is based on FMC's Reofos 65, a triaryl phosphate flame retardant which has found wide acceptance in vinyl, rubber, and other polymer systems. Reofos 1884 contains no water because it is a homogeneous mixture of Reofos 65 and a nonionic emulsifying agent.

Typical properties

Acid number	0.26 mg KOH/g
Color (APHA)	150-200
Specific gravity (20°/20°C)	1.145-1.161

Weight loss, % (neat)	**105° C**	**155° C**
2 hours	0.224	0.40
4 hours	0.235	0.77
24 hours	0.466	3.82

Table 15.75: Proprietary Triaryl Phosphate Ester *(75)*

SANTICIZER 143

Table A. Properties

Phosphorus, %	8.2 (Calc)
• Acidity (meq/100g) max.	0.20
• Appearance	Clear, oily liquid
• Color (APHA) [max.]	100
• Moisture % max.	0.15%
• Refractive Index (@25°C)	1.539 – 1.545
• Specific Gravity (25°/25°C)	1.144 – 1.158
Density lbs./gal.	9.58
Viscosity (Centistokes)	
@ 0°C	297
@ 25°C	44.2
@ 100°C	3.87
Coefficient of Thermal Exp. @10-40°C (cc/cc/°C)	0.00070
Flash Point (C.O.C.) [°F.]	475
Fire Point (C.O.C.) [°F.]	525
Sol. In Water @ 25°C,%	<0.001
CAS Number	56803-37-3 29761-21-5

• Specification

(continued)

Table 15.75: (continued)

Table B. Comparative Performance Data of Santicizer® 143 in Clear Polyvinyl Chloride Film*

	Phosphate Ester						
	Santicizer® 143			**Santicizer® 148**		**Isopropylated Triphenyl (K-100)[3]**	**Tricresyl (TCP)**
PHR Plasticizer	**30**	**40**	**50**	**40**	**50**	**50**	**50**
Hardness (Shore A)	96	90	84	86	78	84	80
Brittle Temp. (°C)	20	9	−2	−10	−20	−2	−3
Low-temp. Flex. (°C)	15	4	−8	−13	−28	−7	−8
Volatility (% Plast. Lost)	2.7	3.0	3.5	2.8	3.3	3.3	1.5
Oil Extraction (% Lost)	1.2	1.5	2.0	1.8	2.3	1.5	0.5
Tensile Strength (PSI)	3570	3350	3135	3200	2805	3120	3220
% Elongation at Break	235	290	325	320	365	320	330
100% Modulus (PSI)	3800	3040	2380	2500	1690	2475	1990
Oxygen Index	32.6	31.6	30.4	29.0	27.8	31.5	31.4
Monsanto Two-foot Tunnel							
Flame Spread (in.)	3.1	3.2	3.3	3.4	3.5	3.5	3.0
% Light Transmittance	18	16	15	33	32	10	5
Vertical Burn (CCT 191B, 5903)							
After-flame (sec.)	32	17	10	1.5	0.4	17	13
Char Length (in.)	3.0	2.6	2.2	1.8	1.7	2.2	2.0
NBS Smoke Chamber							
Dm Flaming Mode	236	275	305	155	171	345	303
Dm Smoldering Mode	128	141	157	85	98	188	163

Formulation

Geon[1] 102 EP	100 Parts
Plasticizer	as given
Drapex[2] 10.4	3 Parts
Mark[3] WS	2 Parts

[1]B.F. Goodrich Inc.
[2]Argus Chemical Corp.
[3]FMC Corp.

*These flammability test results are not intended to reflect performance of these or any other materials under actual fire conditions. Each user should determine independently whether potential fire hazards are associated with the finished products and whether Santicizer 143 is suitable for the particular use.

Table 15.76: Tributoxyethyl Phosphate *(76)*

KP-140®

KP-140 is tributyoxyethyl phosphate. Its CAS number is 78-51-3.

Formula

The formula of KP-140 is $(C_4H_9OC_2H_4O)_3PO$

Specifications

Specific gravity at 20°C	1.016-1.023 (ASTM D263-69)
Moisture	0.2% w/w max (ASTM D364-64)
Colour (Pt-Co: APHA)	75 max (ASTM D1209-69)

Typical properties

The properties shown in the following tables are typical and do not represent specification limits

Property	KP-140
Odour	mild, butyl type
Total acid number	<0.5 mgKOH/g
Boiling range at 4 mm Hg (533 Pa),	215 to 228°C
Mid-boiling point at 4 mm Hg (533 Pa)	222°C
Freezing point	<−70°C (viscous liquid)
Pour point	<−70°C
Flash point (PMCC)	224°C (435°F)
Fire point	252°C (485°F)
Viscosity at 20°C	12.2 cp (mPa.s)
Vapour pressure	
at 150°C	<0.10 mm Hg (13.3 Pa)
at 200°C	1.6 mm Hg (213 Pa)
Surface tension at 20°C	30 dynes/cm (mN/m)
Refractive index N_D^{25}	1.434 ± 0.002
Specific heat at 50 to 150	0.58 average
Solubility	
in water at 25°C	0.11% by weight
in water at 25°C	approx. 7.3% by volume
in mineral oil at 25°C	approx. 7.0% by volume
in gasoline at 25°C	complete
General solubility	Insoluble or limited solubility in glycerine, glycols, and certain amines. Soluble in most other organic liquids.
Thermal expansion at 10-40°C,	0.00081 per °C
Density at 20°C	1018 kg/m³ (8.50 lb/US gallon)

Table 15.77: Tributyl Phosphate *(76)*

Reomol TBP

Formula	$(C_4H_9O)_3$ PO	MW (mol) 266
Specifications		
Specific gravity @ 20°/20°C	0.977-0.983 (ASTM D268-62/3)	
Moisture, % by weight	0.20 max (ASTM D1364-62)	
Color Pt-Co (APHA)	50 max (ASTM D1209-62)	
Typical properties		
Odor	normal characteristic	
Acidity, % as acetic acid	0.05 (ASTM D1613-61T)	
Boiling range @ 4 mm Hg (533 Pa), °C	137-145	
Mid-boiling range @ 4 mm Hg (533 Pa), °C	139	
Freezing point, °C	<−80	
Pour point, °C	<−80	
Flash point, °C (°F), PMCC	115 (239)	
Fire point, °C (°F)	182 (360)	
Viscosity, cp (mPa•s) @ 20°C	3.7	
Vapor pressure @ 150° C, mm Hg (kPa)	7.3 (0.97)	
@ 200° C, mm Hg (kPa)	>500 (66.6)	
Surface tension @ 20° C, dyne/cm (m N/m)	29	
Refractive index, N_D^{25}	1.423 ± 0.001	
Solubility, in water @ 25°C	0.1%	
water in @ 25°C	7.0%	
in mineral oil @ 25°C	complete	
in gasoline @ 25°C	complete	
General solubility	Insoluble or limited solubility in glycerine, glycols, and certain amines. Soluble in most other organic liquids.	
Thermal expansion @ 10 to 40°C	0.00086 per °C	
Lb/U.S. gal (kg/m³) @ 20°C	8.14 (975)	

Table 15.78: Triphenyl Phosphate *(75)*

Table A. Properties

Molecular Weight	326
Phosphorus, %	9.5 (Calc)
• Acidity (meq/100 gm. max)	0.10
• Appearance	White flakes
• Color (APHA) [max.]	20 (molten)
• Odor (max.)	Very faint, aromatic
Refractive Index (@ 60°C)	1.550
Specific Gravity (60°/20°C)	1.268
Density (@ 60°C) ca. lbs./gal.	10.5
Crystallizing Point (°C)	49
Boiling Point @ 10mm Hg, °C	238
Vapor Pressure (mm Hg)	
@ 150°C	>0.1
@ 200°C	1.3
@ 250°C	18.2
Viscosity (Centistokes)	
@ 55°C	7.8
@ 98.9°C	2.9
Flash Point (C.O.C.) [°F.]	437
Solubility In Water @ 34°C,%	0.002
CAS Number	115-86-6

• Specification

(continued)

Table 15.78: (continued)

Table B. Compatibility of Triphenyl Phosphate With Various Resins

	(PHR)
Polyvinyl chloride	20
Polyvinyl acetate	80
Nitrocellulose	75
Cellulose acetate	35
Cellulose acetate-propionate	50
Cellulose acetate-butyrate	50
Ethyl cellulose	30
Acrylics	25
Santolite® MHP resin	100
Neoprene	50
Nitrile rubber	50
Phenolic	50

Table C. Triphenyl Phosphate Performance in Cellulosic Resins

Resin	Cellulose Acetate	Ethyl Cellulose		Nitro-Cellulose		Cellulose Acetate-Butyrate
PHR	42.5	0	15	0	50	33
Solution Temperature °C.	180	–	–	–	–	–
Yield, p.s.i.	–	6755	4550	–	–	–
Tensile, p.s.i.	–	8960	6685	8533	4410	2500
Elongation, %	–	30	30	6	8	10
Hardness	81	100	70	–	–	–
Sward Hardness	–	–	–	–	–	40
Volatility	–	E	E	–	–	–
Flexibility Schopper Fold Cycles	–	–	–	20	24	–
Flexural Strength, p.s.i.	9020	–	–	–	–	–
Moisture Permeability, %	–	–	–	100	56	–
% Water Absorbed in 24 hrs.	1.17	–	–	–	–	–

PHOSPHITES

Table 15.79: Dialkyl Hydrogen Phosphites *(64)*

PHYSICAL PROPERTIES

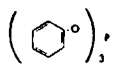
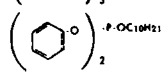
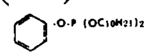
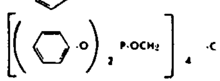
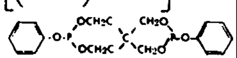
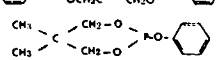
Property	Dimethyl Hydrogen Phosphite	Diethyl Hydrogen Phosphite	Dibutyl Hydrogen Phosphite	Bis(2-ethylhexyl) Hydrogen Phosphite
Formula	$(CH_3O)_2P(O)H$	$(C_2H_5O)_2P(O)H$	$(C_4H_9O)_2P(O)H$	$(C_8H_{17}O)_2P(O)H$
Molecular Weight	110.1	138.1	194.2	306.4
Appearance	colorless liquid	colorless liquid	colorless liquid	colorless liquid
Odor	mild, characteristic	mild, pleasant	mild, pleasant	mild, suggestive of octyl alcohol
Boiling Point	72-3°C/25 mm	65-66°C/6 mm	118-9°C/7 mm	163-4°C/3 mm
Specific Gravity 20°/4°	1.200	1.079	0.995	0.937
Index of Refraction, n_D^{20}	1.4016	1.4073	1.4238	1.4423
Flash Point, Cleveland, open cup	205°F	195°F	250°F	330°F
Fire Point, Cleveland, open cup	220°F	220°F	300°F	400°F
Viscosity (Centistokes) 77°F	1.08	1.21	2.36	6.54
100°F	0.92	1.03	1.90	4.72
210°F	0.51	0.56	0.89	1.59
Toxicity (single dose oral LD_{50}, rats), mg/kg	3,050	1,000	3,900	11,900
Acidity	neutral	neutral	neutral	neutral
Solubility in water:	sol., hydrolyzes	sol., hydrolyzes	sl. sol., slowly hydrolyzes	insol., very slowly hydrolyzes
in other solvents:	miscible with alcohol, ether, acetone and most common organic solvents.			

Table 15.80: Trialkyl Phosphites *(64)*

PHYSICAL PROPERTIES

Property	Trimethyl Phosphite	Triethyl Phosphite	Tris(2-chloroethyl) Phosphite	Triisopropyl Phosphite	Tributyl Phosphite	Triisooctyl Phosphite	Tris(2-ethylhexyl) Phosphite
Formula	$(CH_3O)_3P$	$(C_2H_5O)_3P$	$(ClC_2H_4O)_3P$	$(C_3H_7O)_3P$	$(C_4H_9O)_3P$	$(C_8H_{17}O)_3P$	$(C_8H_{17}O)_3P$
Molecular Weight	124.08	166.2	269.5	208.2	250.3	418.6	418.6
Appearance	colorless liquid	colorless liquid	colorless liquid	colorless liquid	colorless liquid	colorless liquid	colorless liquid
Odor	penetrating	sweet, characteristic	mild, characteristic	sweet, characteristic	mild, not unpleasant	mild, not unpleasant	mild, not unpleasant
Boiling Point	111-112°C	65°C/24 mm	119°C/0.15 mm	94-6°C/50 mm	118-25°C/7 mm	161-4°C/0.3 mm	163-4°C/0.3 mm
Specific Gravity 20°/4°	1.046	0.969	1.353	0.914	0.925	0.891	0.902
Index of Refraction, n_D^{20}	1.4076	1.4131	1.4878	1.4101	1.4327	1.4498	1.4494
Flash Point, Cleveland, open cup	100°F	130°F	375°F	165°F	250°F	385°F	365°F
Fire Point, Cleveland, open cup	100°F	160°F	410°F	195°F	275°F	410°F	400°F
Viscosity (Centistokes) 77°F	0.58	0.74	5.22	1.18	2.08	9.49	8.35
100°F	0.52	0.65	4.11	0.99	1.65	6.85	5.86
210°F	0.32	0.40	1.45	0.57	0.86	2.24	1.90
Toxicity (single dose oral LD_{50}, rats), mg/kg	2,000	3,160	250	2,300	3,000	9,200	-----
Solubility in water:	insol. but reacts with	sl. sol., hydrolyzes	insol., slowly hydrolyzes	insol., slowly hydrolyzes	insol., slowly hydrolyzes	insol., very slowly hydrolyzes	insol., very slowly hydrolyzes
In other solvents:	miscible with alcohol, acetone, benzene, ether, heptane, carbon tetrachloride, and most of the common organic solvents.						

Table 15.81: Tertiary Phosphites *(27)*

Name	Formula	Molecular Weight	Oral Toxicity LD50 Microliters per Kg of Rat Wt.	Color and Form	Phosphorus Content % P	Melting Point °C	Boiling Point °C	Refractive Index n 25/D	Specific Gravity 25/15°C	Flash Point COC°F	Viscosity Centistokes 68°F	100°F	210°F	Vapor Pressure
Trimethyl Phosphite	$(CH_3O)_3P$	124	2000	Water-white liquid	24.97	<−78	111±1	1.404	1.045	130	—	0.51	0.30	10 mm at 12°C 100 mm at 55°C
Triethyl Phosphite	$(C_2H_5O)_3P$	166	3160	Water-white liquid	18.67	—	154±1	1.413	0.954	—	—	—	—	—
Tri(2-ethylhexyl) Phosphite	$(C_8H_{17}O)_3P$	418	—	Straw-colored liquid	7.45	glass at low temp.	—	1.451	0.897	340	8.5	5.03	—	—
Tridecyl Phosphite (iso)	$(C_{10}H_{21}O)_3P$	502	>10000	Water-white liquid	6.17	< 0	180 at 0.1 mm	1.454	0.886	455	—	11.24	2.90	—
Trilauryl Phosphite	$(C_{12}H_{25}O)_3P$	586	> 3160	Water-white liquid	5.29	<10	—	1.456	0.866	—	—	—	—	—
Trioctadecyl Phosphite	$(C_{18}H_{37}O)_3P$	838	>10000	White waxy solid	3.70	45-47	—	—	0.940*	—	—	—	—	—
Trilauryl Trithiophosphite	$(C_{12}H_{25}S)_3P$	634	>10000	Light straw-colored liquid	4.89	20	—	1.502	0.915	430	—	24.7	5.7	0.01 mm at 200°C
Triphenyl Phosphite		310	Approx. 2800	Water-white to pale yellow liquid	10.0	22-25	155-160 at 0.1 mm	1.589	1.184	425	—	8.34	2.07	—
Diphenyldecyl Phosphite (iso)		374	>10000	Water-white liquid	8.28	18	—	1.516	1.024	425	—	7.82	2.26	—
Phenyldidecyl Phosphite (iso)		438	>10000	Water-white liquid	7.07	<0	—	1.478	0.940	425	—	8.95	2.42	—
"Pentite" — [tetra(diphenyl phosphito) pentaerythritol]		989	1500	White waxy solid	12.4	30-60	—	—	1.240	—	—	—	—	—
"Dipentite" — [diphenyl pentaerythritol diphosphite]		380	5000	White solid	16.3	70-80	190-200 at 0.1 mm	—	—	—	—	—	—	—
Phenylneopentyl Phosphite		226	1780	Water-white liquid	13.70	19	138-140 at 10 mm	1.517	1.135	—	—	—	—	—
1620 Polymeric Phosphite	Bisphenol A-Pentaerythritol Phosphite	Av 1100	>3160	White solid	16.1±0.2	100-110	—	—	—	—	—	—	—	—

*Density

Table 15.82: Organophosphites *(27)*

PHYSICAL DATA

	Triphenyl	Diphenyldecyl	Phenyldidecyl	Tridecyl
Phosphorus Content	10%	8.28%	7.07%	6.17%
Melting Point	22°-25°C.	18°C.	< 0°C.	< 0°C.
Boiling Point at 0.1 mm.	155°-160°C.	—	—	180°C.
Refractive Index, n25/D	1.589	1.5160	1.4785	1.4560
Flash Point (Cleveland open cup)	425°F.	425°F.	425°F.	455°F.
Fire Point (Cleveland open cup)	470°F.	455°F.	470°F.	485°F.
Specific Gravity, 25°/15.5°C.	1.184	1.023	0.940	0.891
Specific Gravity Correction Factor, per 1°C.	0.00085	0.00077	0.00073	0.00066
Pounds per Gallon at 25°C.	9.86	8.520	7.829	7.421
Viscosity in Centistokes:				
at 100°F.	8.34	7.82	8.95	11.24
at 210°F.	2.07	2.26	2.42	2.90

SILICATES

Table 15.83: Ethyl Silicate *(2)*

Silicon Tetraethyl Ester
Ortho-Silicic Acid Ethyl Ester

$Si(OC_2H_5)_4$

Ethyl silicate is a water-white liquid, soluble in alcohol. It hydrolyzes in water to an adhesive form of silicic acid and alcohol. It is used in lacquers and paint as a pigment binder giving films that are resistant to fire and chemicals and are weatherproof. A less pure, higher silica ester, Ethyl Silicate 40, is also available commercially.

Specifications—Tetraethyl Silicate

Acidity (as HCl)	0.05% by wt, max
Available silica (as SiO_2)	28.8%
Boiling point	165.5°C
Boiling range at 760 mm	
Below 160°C	Not more than 5%
Below 170°C	Not less than 95%
Color	Water-white
Purity	97%, min
Specific gravity at 20/20°C	0.933 to 0.938
Weight per gal at 20°C	7.78 lbs

Specifications—Ethyl Silicate

Acidity, maximum acidity (as HCl)	0.1%
Available silica (as SiO_2)	34-42%
Boiling point	165°C
Boiling range at 760 mm	
Below 80°C	None
Below 110°C	Not more than 5%
Color	Light brown
Odor initial	Mild
Specific gravity at 20/20°C	1.050 to 1.070
Weight per gal at 20°C	8.82 lbs

Table 15.84: Summary of Typical Properties of Plasticizers *(75)*

	Phthalates					Adipates	
	*Dioctyl**	Santicizer® 160	Santicizer 261	Santicizer 278	*Dibutyl**	Santicizer 97	Dioctyl
Molecular Weight	391	312	368	455	278	370	371
Acidity (meq./100 gm. max.)**	0.12	•0.37	•0.37	•0.37	0.12	•0.25	•0.25
Appearance	Clear, oily liquid	•Clear, oily liquid	•Clear, oily liquid	•Clear, oily liquid	Clear, oily liquid	•Clear, oily liquid	•Clear, oily liquid
Color (APHA) (max.)	25	•40	•75	•175	20	•50	•25
Moisture (KF in Methanol) % max.	0.10	•0.15	•0.15	•0.15	0.15	•0.10	•0.10
Odor	Slight, characteristic	•Slight, characteristic	•Slight, characteristic	•Slight, characteristic	Slight, characteristic		•Mild
Refractive Index (at 25°C)	1.4845-1.4858	•1.535-1.540	•1.523-1.529	•1.516-1.520	1.4895-1.4915	•1.441-1.447	•1.444-1.448
Specific Gravity (25°/25°C)	0.980-0.985	•1.115-1.123	•1.065-1.074	•1.093-1.100	1.044-1.048	•0.916-0.924	•0.921-0.927
Density (at 25°C) ca. lbs./gal.	8.18	9.3	8.9	9.1	8.72	7.7	7.72
Crystallizing Point (°C)***	–55 (very stiff gel)	<–35	–	–	<–35	–13	<–70
Pour Point (°C)	–47	–45	–45	–6.5	–40	–	–65
Flash Point (C.O.C.) (°F)	425	390	445	440	340	400	377
Fire Point (C.O.C.) (°F)	480	450	–	535	395	450	450
Boiling Point @ 10 mm Hg. °C	236	240	252	243	192	224	224
Vapor Pressure @ 150°C	–	0.14	–	–	.08	–	–
@ 200°C	1.2	1.9	0.5	0.5	14.0	3.3	2.3
@ 250°C	18	14.4	9.7	15	100	27	32
% VOC, EPA method 24****	1.5	2.3	0.7	1.1	14.8	2.8	4.2
Viscosity (centistokes) @ 0°C	348.0	230	–	ca 10,000	55.0	–	–
@ 25°C	58.0	39.5	53	800	15.6	12.8	12.3
@ 98.9°C	4.3	3.42	4.2	11.5	2.4	2.6	2.4
Surface Tension @ 20°C (dynes/cm.)	33 (25°C)	39.9 (25°C)	35.3 (24°C)	34.8 (25°C)	35 (30°C)	30.3 (25°C)	29
Solubility in Water @ 25°C (%)	<0.005	0.0003 (30°C)	0.00003	Practically insol.	<0.001 (30°C)	<0.01	<0.01
Hydroxyl #	–	<1	2	2-4	–	–	–

(continued)

Table 15.84: (continued)

	Phosphates					Specialty Modifiers	
	Santicizer 141	Santicizer 148	Santicizer 2148	Santicizer 143	Santicizer 154	HB-40	
Molecular Weight	362	390	--	–	368	–	**Molecular Weight**
Acidity (meq./100 gm. max.)**	•0.20	•0.20	•0.20	•0.20	•0.25	–	**Acidity** (meq./100 gm. max.)**
Appearance	•Clear, oily liquid	•Clear, oily liquid	•Clear, oily liquid	•Clear, oily liquid	•Clear, oily liquid	Clear, oily liquid	**Appearance**
Color (APHA) (max.)	•40	•100	•200	•100	•60	•450	**Color (APHA) (max.)**
Moisture (KF in Methanol) % max.	•0.10	•0.10	•0.10	•0.15	•0.15	•150 ppm	**Moisture (KF in Methanol) % max.**
Odor	•Essentially odorless	•Essentially odorless	•Essentially odorless	--	•Essentially odorless	Faint, characteristic	**Odor**
Refractive Index (at 25°C)	•1.506-1.510	•1.501-1.507	•1.494-1.502	•1.539-1.545	•1.5535-1.5565	•1.560-1.575	**Refractive Index (at 25°C)**
Specific Gravity (25°/25°C)	•1.085-1.091	•1.061-1.071	•1.028-1.044	•1.144-1.158	•1.175-1.185	1.001-1.009 (25°/15.5°C)	**Specific Gravity (25°/25°C)**
Density (at 25°C) ca. lbs./gal.	9.1	8.94	8.65	9.6	9.8	8.4	**Density (at 25°C) ca. lbs./gal.**
Crystallizing Point (°C)***	–	<-35	0	–	<-20	–	**Crystallizing Point (°C)*****
Pour Point (°C)	-54	<-50	–	–	-25	-26	**Pour Point (°C)**
Flash Point (C.O.C.) (°F)	435	465	445	475	505	345	**Flash Point (C.O.C.) (°F)**
Fire Point (C.O.C.) (°F)	460	500	500	525	590	385	**Fire Point (C.O.C.) (°F)**
Boiling Point @ 10 mm Hg. °C	239 (dec)	245 (dec)	230 (dec)	–	258	180	**Boiling Point @ 10 mm Hg. °C**
Vapor Pressure @ 150°C	0.2	<0.1	–	–	–	2.6	**Vapor Pressure @ 150°C**
@ 200°C	1.6	0.5	<0.2	–	1.0	22	**@ 200°C**
@ 250°C	–	–	–	–	7.4	95	**@ 250°C**
% VOC, EPA method 24*****	2.5	1.6	0.4	–	0.7	–	**% VOC, EPA method 24*******
Viscosity (centistokes) @ 0°C	61.0	95	–	297	475	1,200-2,000	**Viscosity (centistokes) @ 0°C**
@ 25°C	16.4	22.5	24	44.2	58	75-200	**@ 25°C**
@ 98.9°C	2.5	3.0	3.5	–	–	3.9-4.4	**@ 98.9°C**
Surface Tension @ 20°C (dynes/cm.)	33.4 (22°C)	–	36.4	–	38.6 (23°C)	40.1	**Surface Tension @ 20°C (dynes/cm.)**
Solubility in Water @ 25°C (%)	0.003	<0.003	<0.2	<0.001	<0.001	Practically insol.	**Solubility in Water @ 25°C (%)**
Hydroxyl #	<3	<3	>4	<3	<1	<1	**Hydroxyl #**

•Specification.
*Registered Trademark of Monsanto Co.
'This product is no longer manufactured by Monsanto. Data is included for reference only.
**To convert from meq/100 gram, multiply by 0.559 to obtain "acid no." (milligrams KOH per gram of sample).
***Crystallizing point is NOT a valid predictor of low temperature performance in a polymer system.
****Tested per ASTM-2369 as specified in EPA method 24. Tested WITH toluene solvent as specified in ASTM method. Testing without toluene reduces measured VOC 10-50% below values reported here.

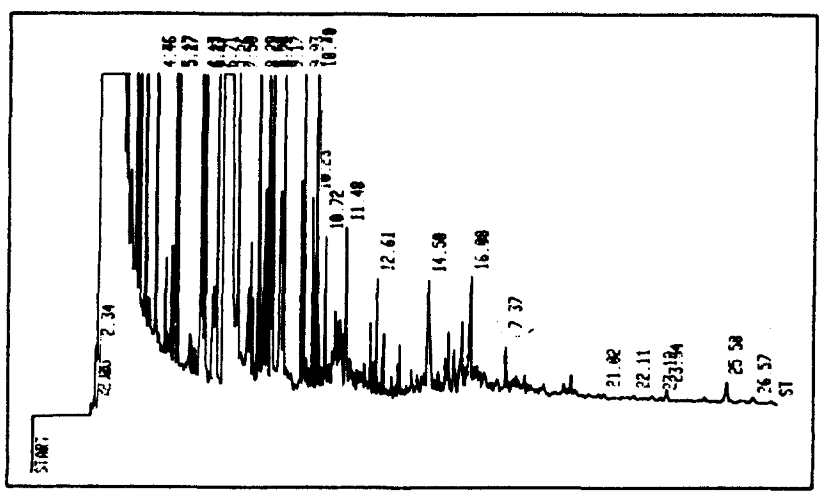
HPLC and UV Data

GC–FID CHROMATOGRAMS

Table 16.1: Methylene Chloride *(56)*

These capillary GC-FID Chromatograms show the significant decrease in impurity content from raw material to finished product.

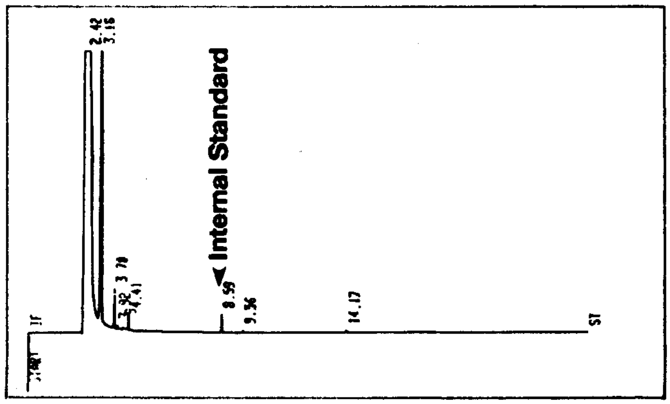
Raw Material: Methylene Chloride
500 → 5 concentration



(continued)

Table 16.1: (continued)

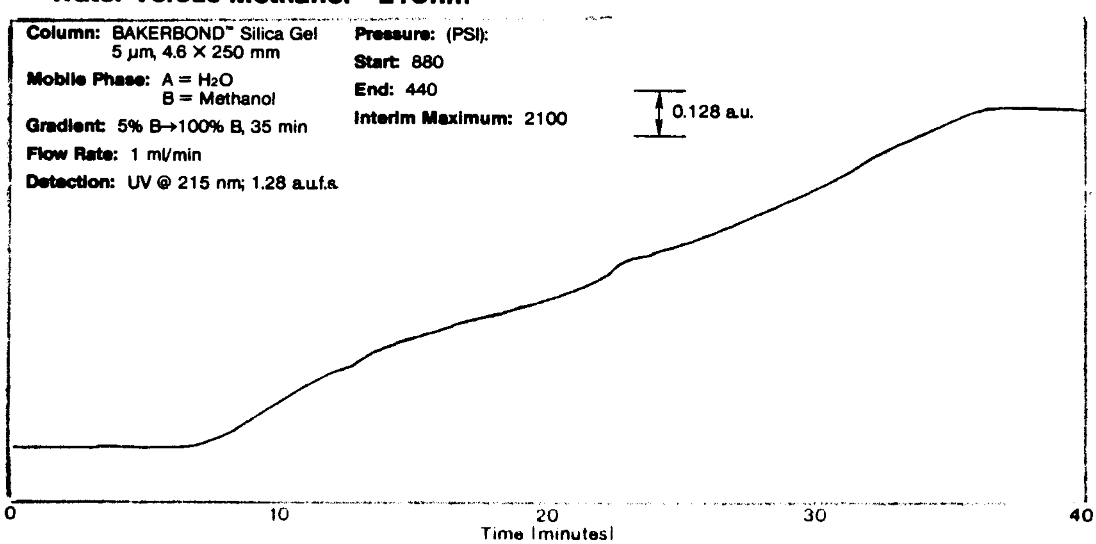
Finished Product: HPLC Methylene Chloride
#9315
500 → 5 concentration



HPLC GRADIENT CHROMATOGRAMS

Table 16.2: Water vs Methanol *(56)*

Water Versus Methanol - 215nm



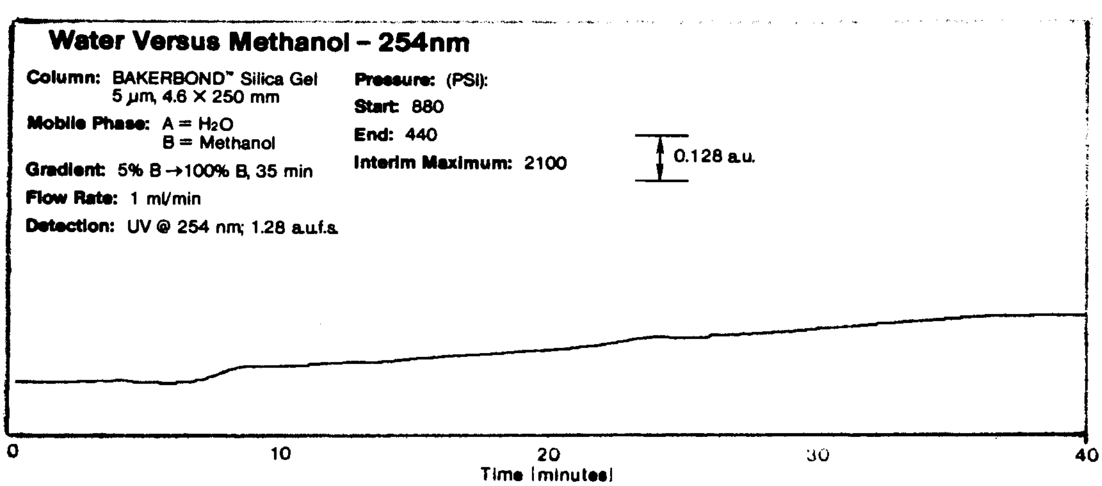
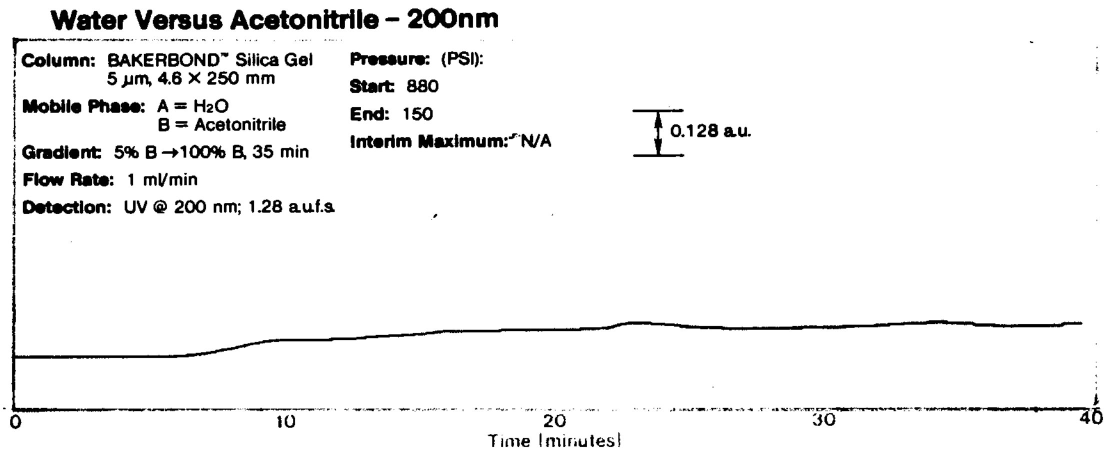
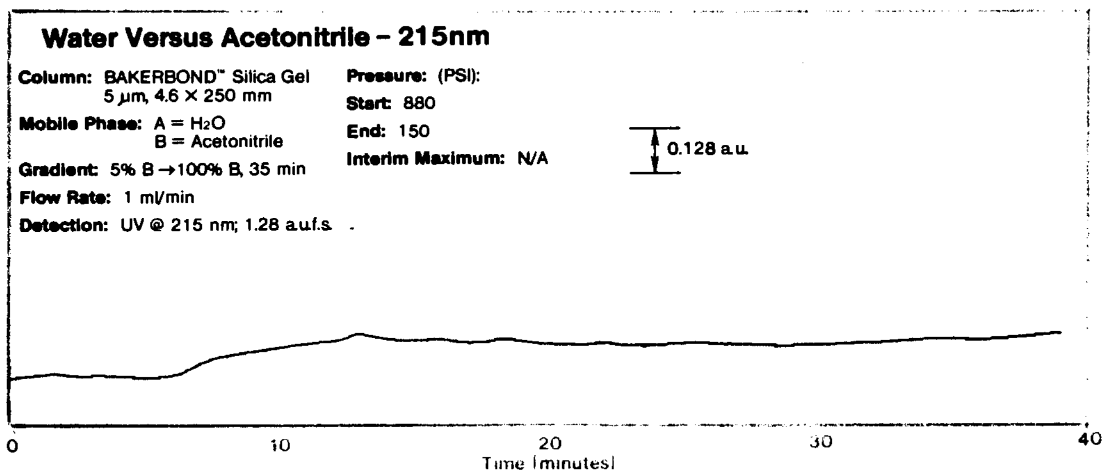


Table 16.3: Water vs Acetonitrile *(56)*





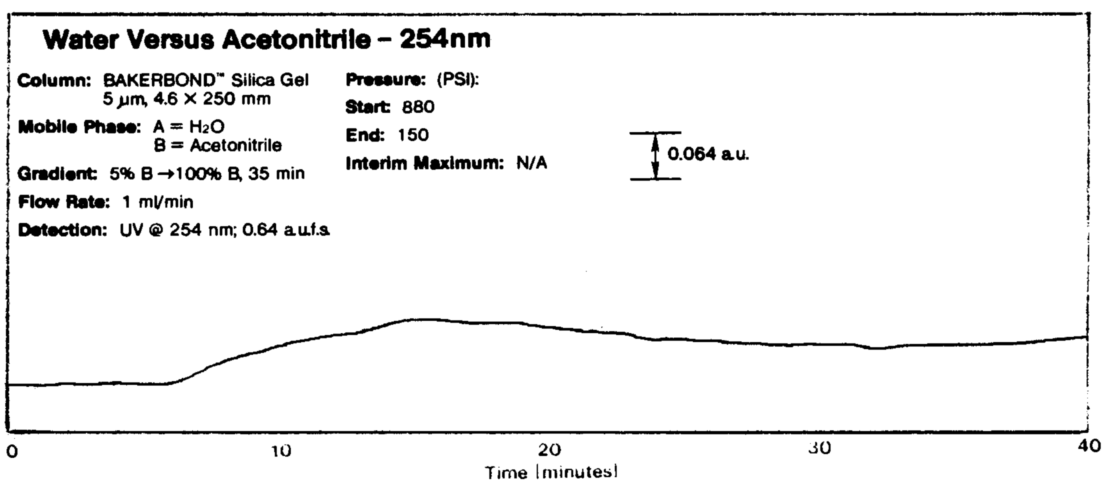
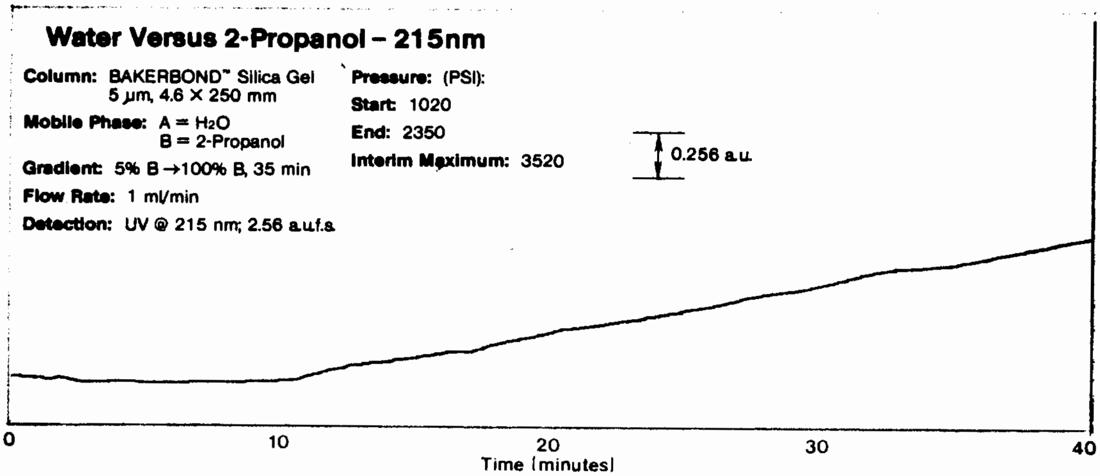


Table 16.4: Water vs 2-Propanol *(56)*



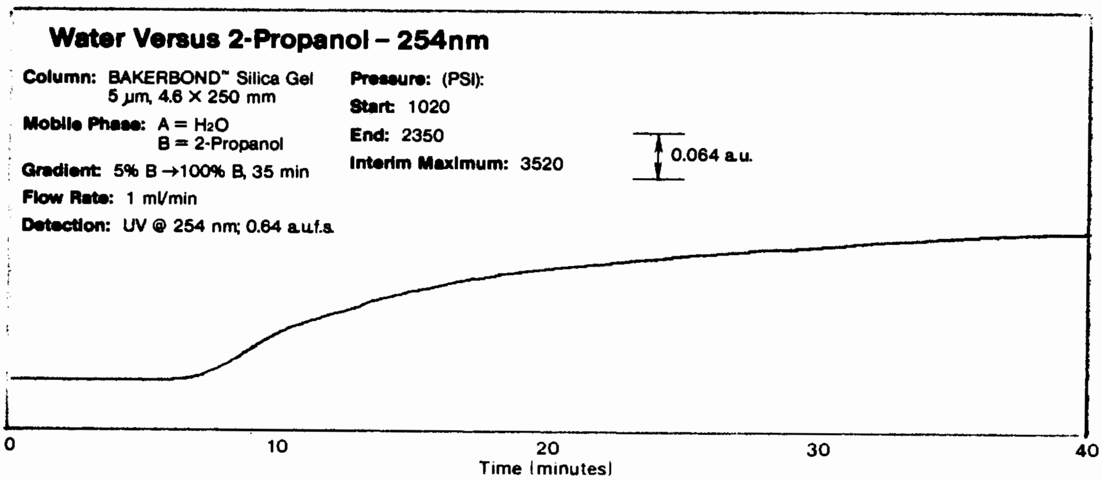
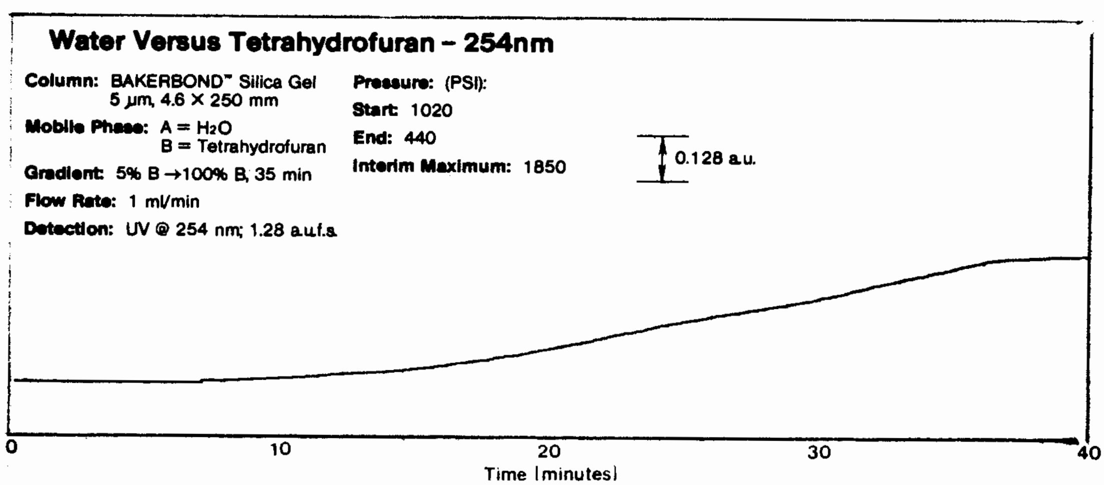


Table 16.5: Water vs Tetrahydrofuran *(56)*



(continued)

Table 16.5: (continued)

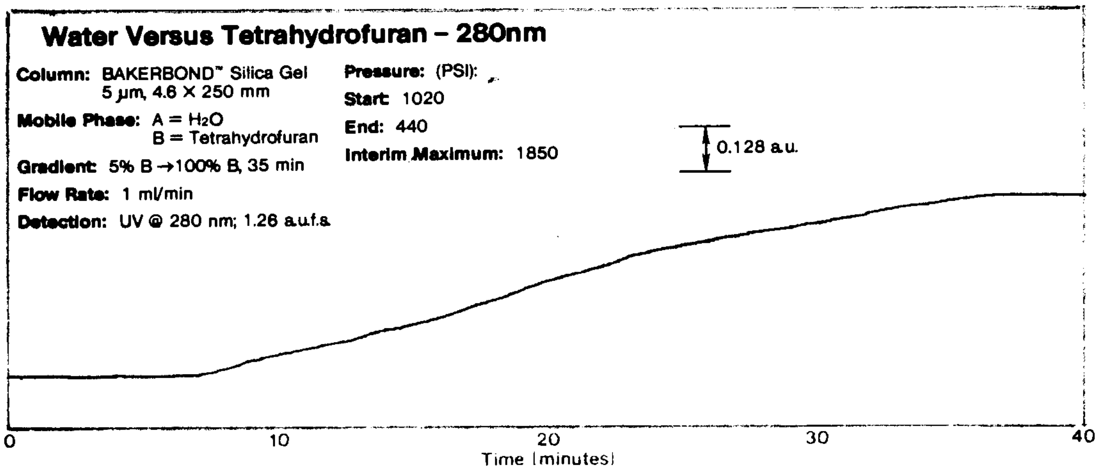
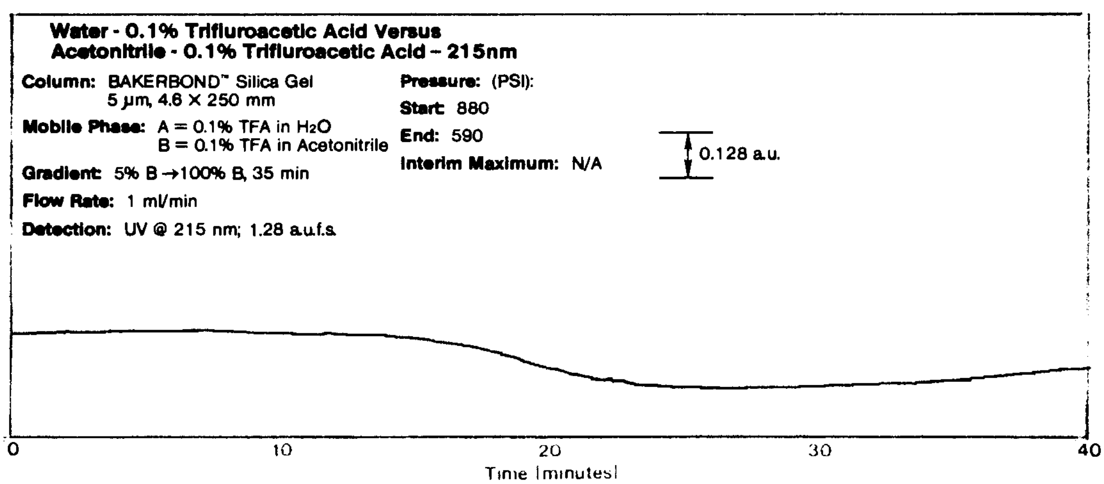
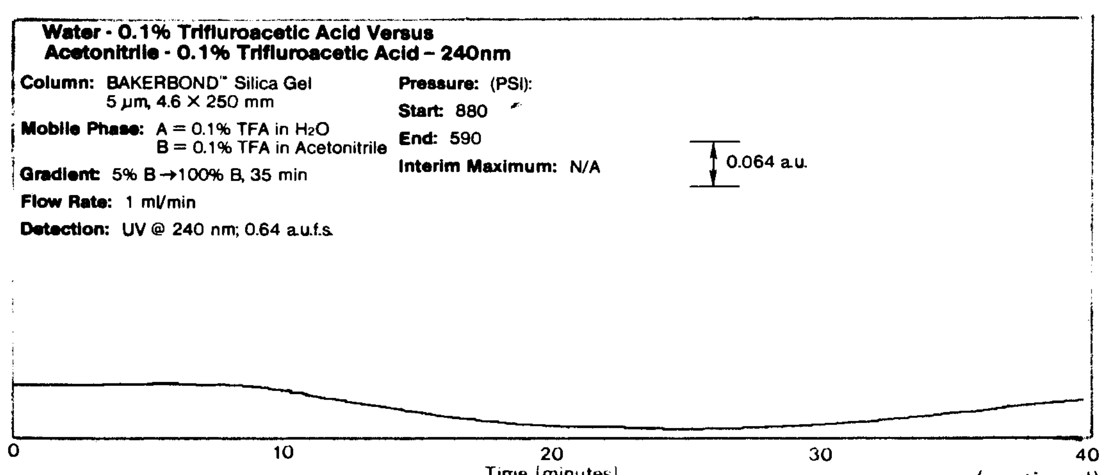


Table 16.6: Water–0.1% Trifluoroacetic Acid vs Acetonitrile–0.1% Trifluoroacetic Acid *(56)*





(continued)

Table 16.6: (continued)

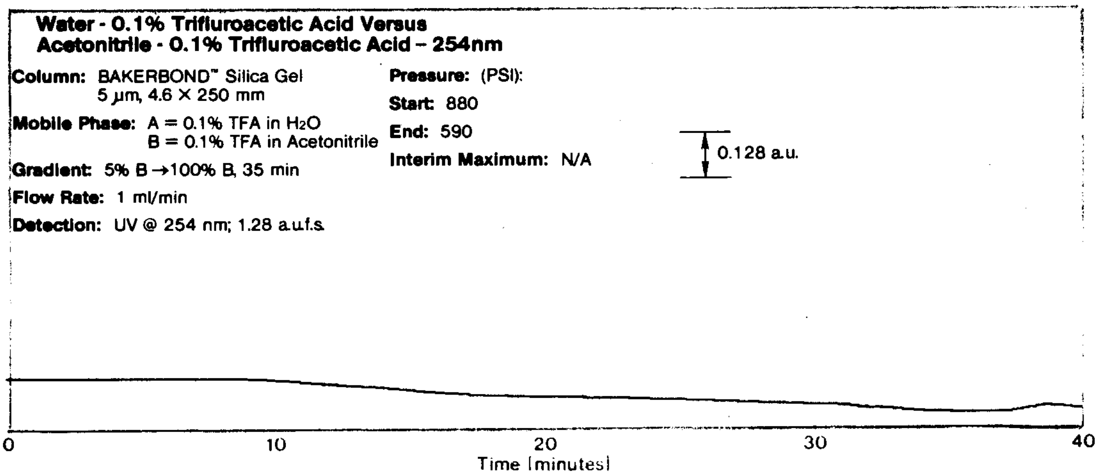
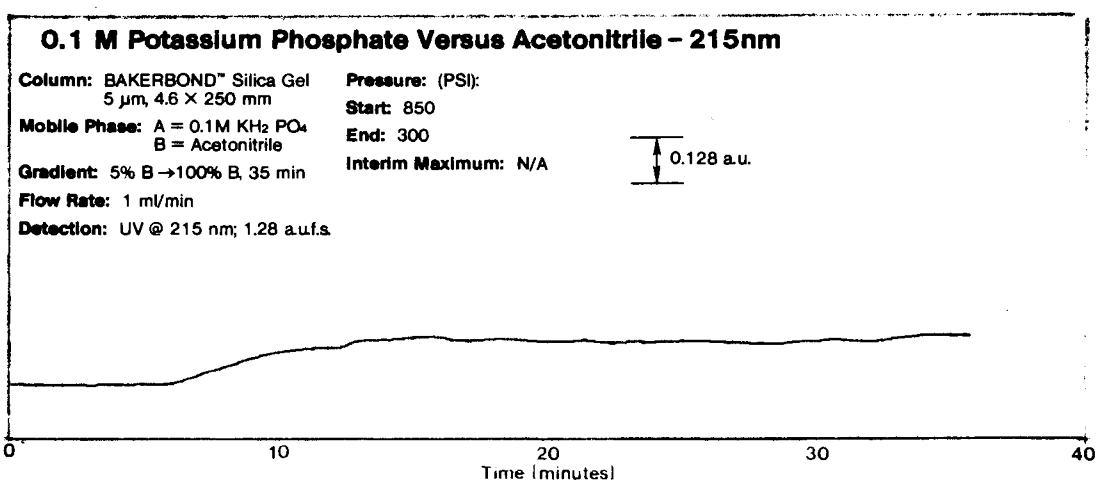


Table 16.7: 0.1 M Potassium Phosphate vs Acetonitrile *(56)*



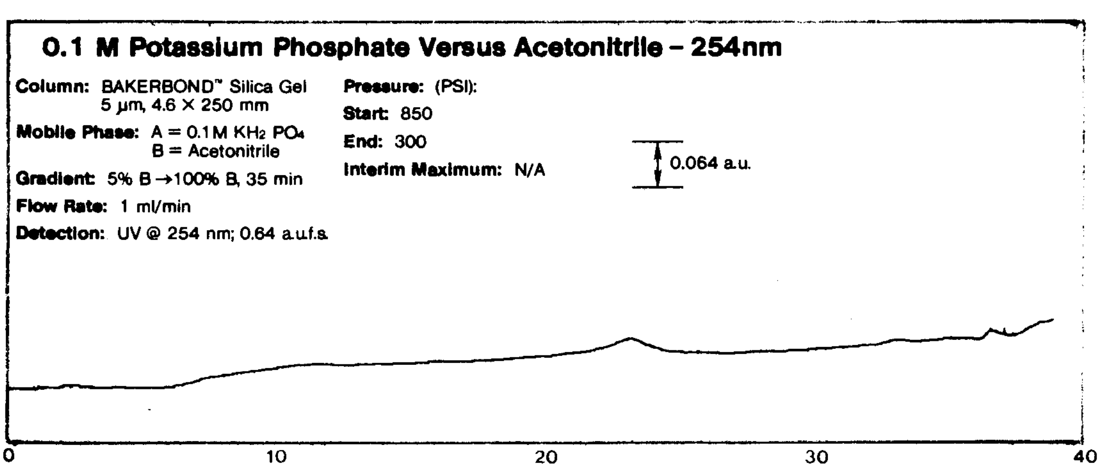
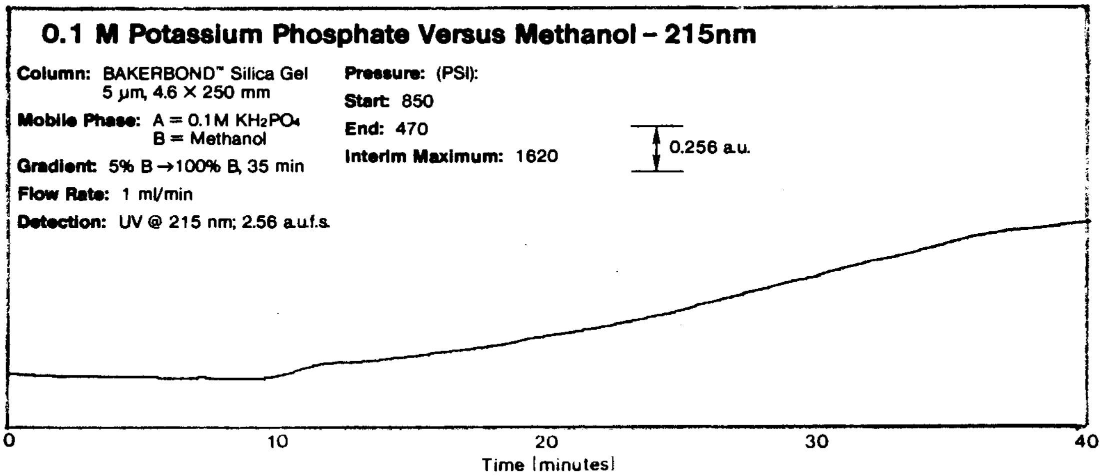


Table 16.8: 0.1 M Potassium Phosphate vs Methanol *(56)*



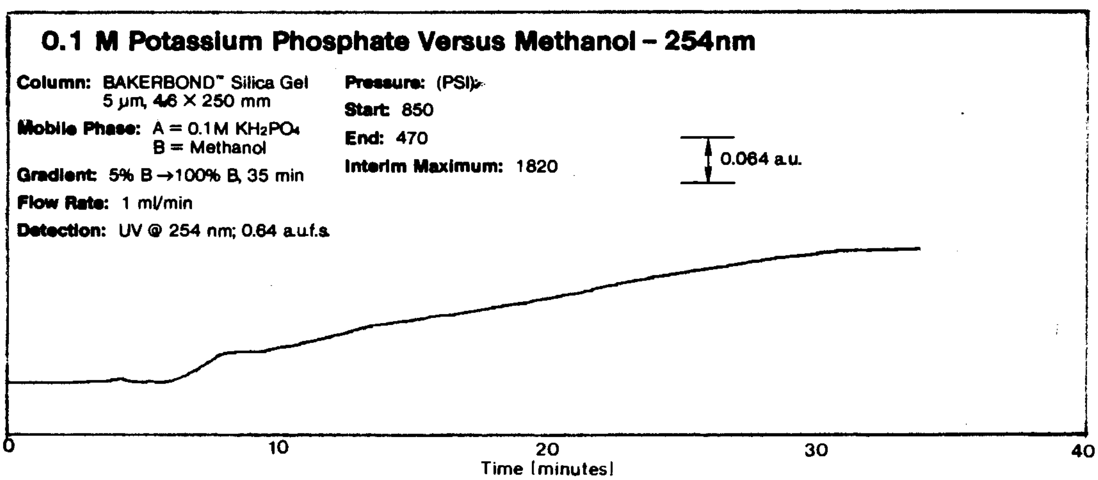
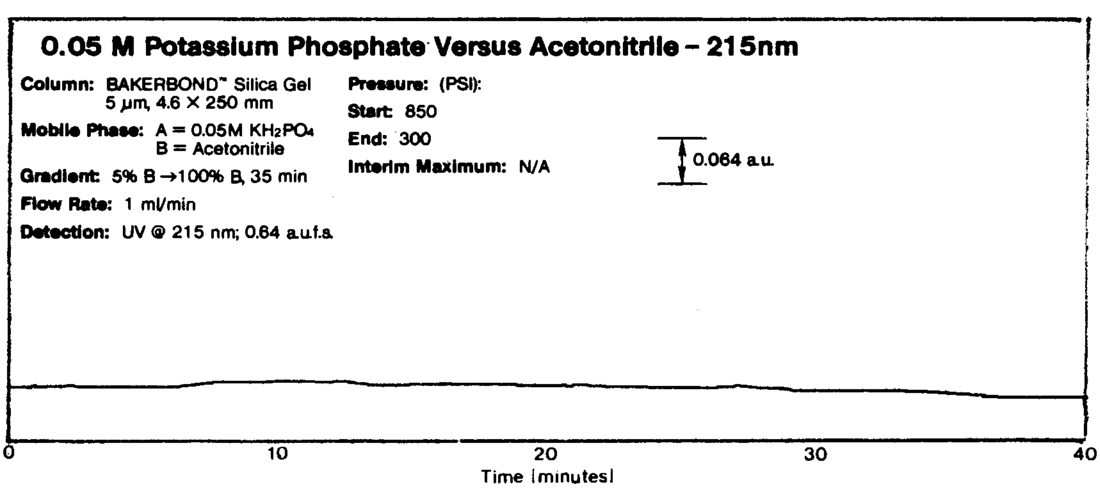


Table 16.9: 0.05 M Potassium Phosphate vs Acetonitrile *(56)*



(continued)

Table 16.9: (continued)

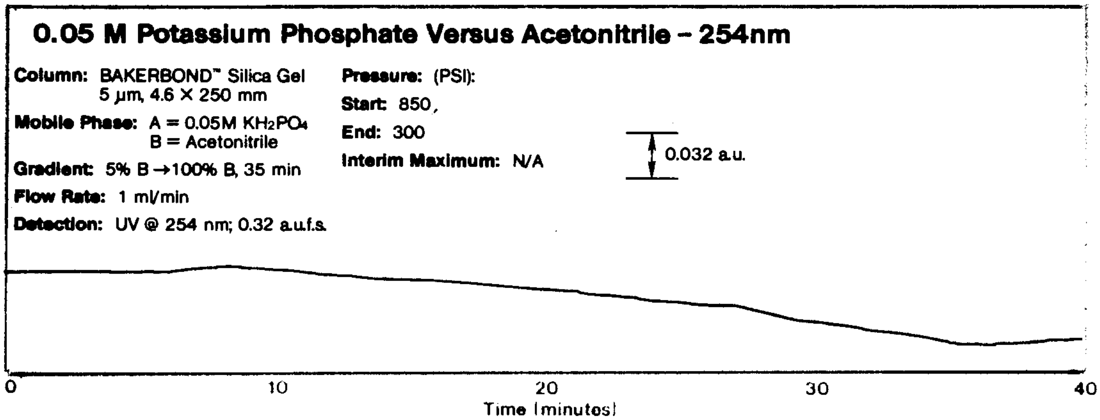
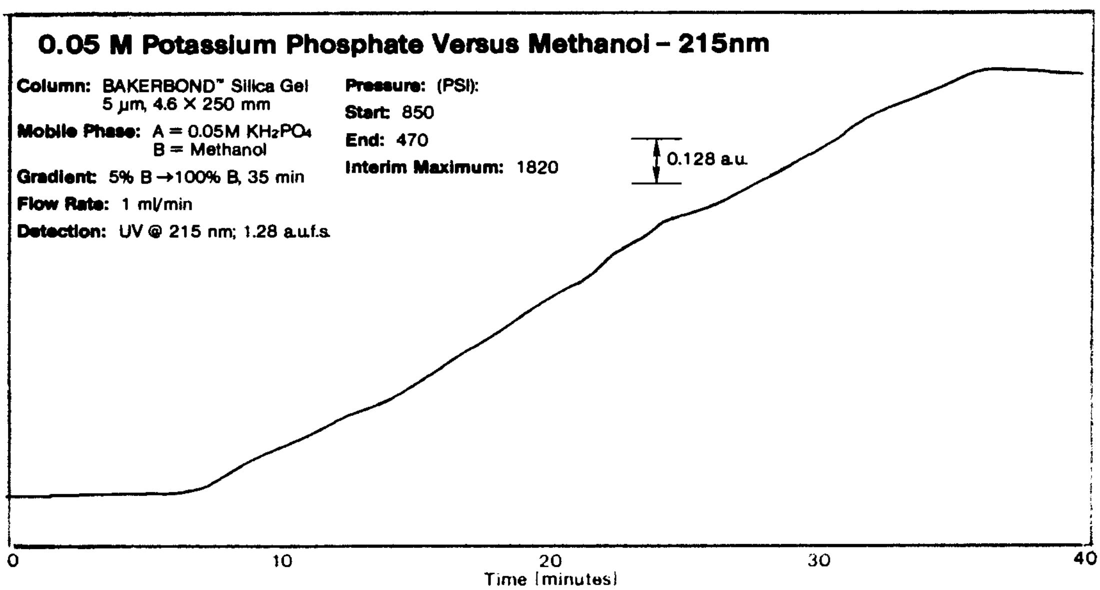


Table 16.10: 0.05 M Potassium Phosphate vs Methanol *(56)*



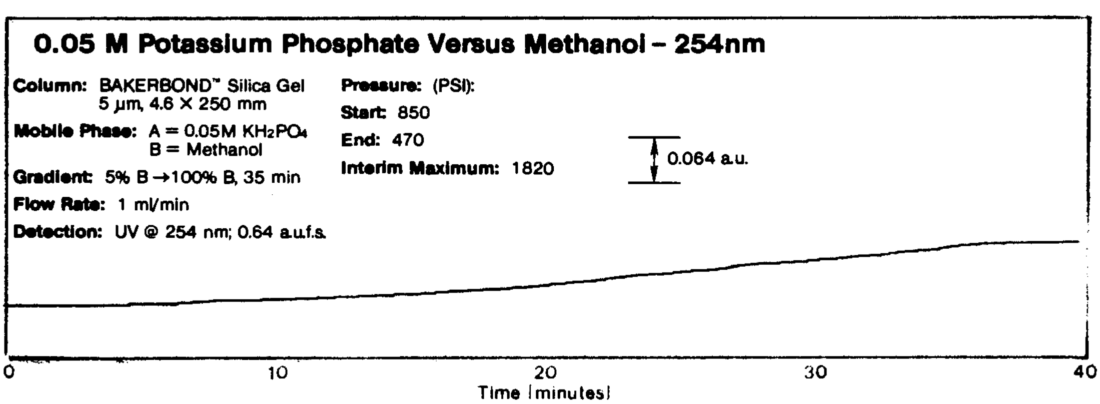
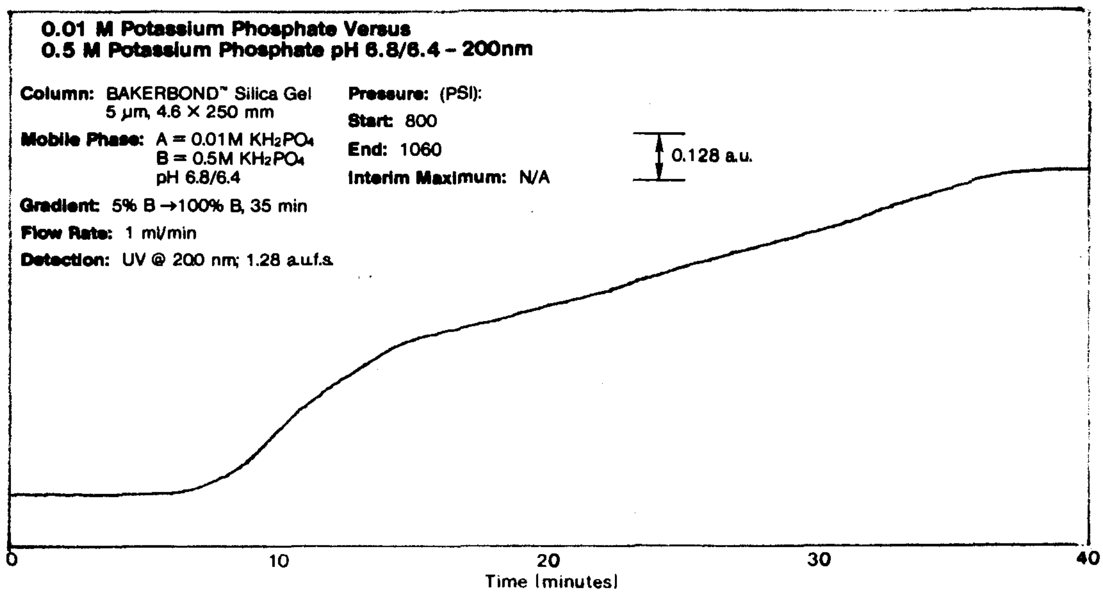
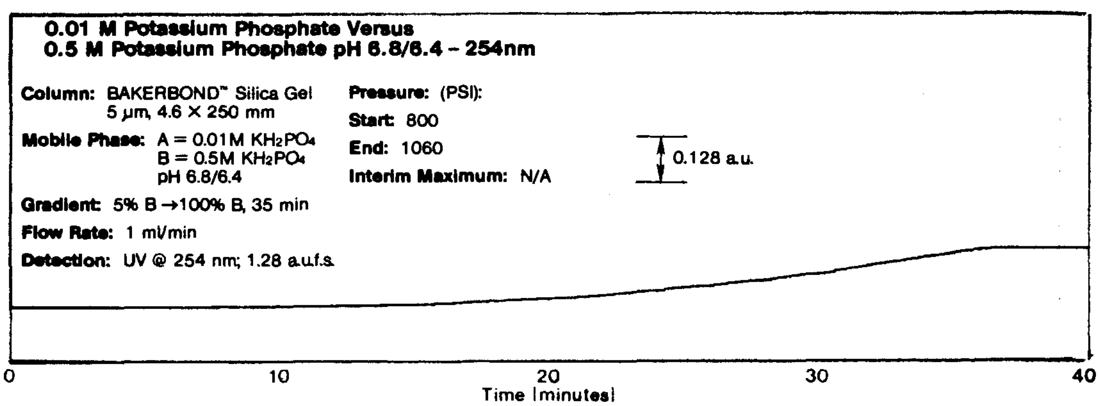


Table 16.11: 0.01 M Potassium Phosphate vs 0.5 M Potassium Phosphate pH 6.8/6.4 *(56)*





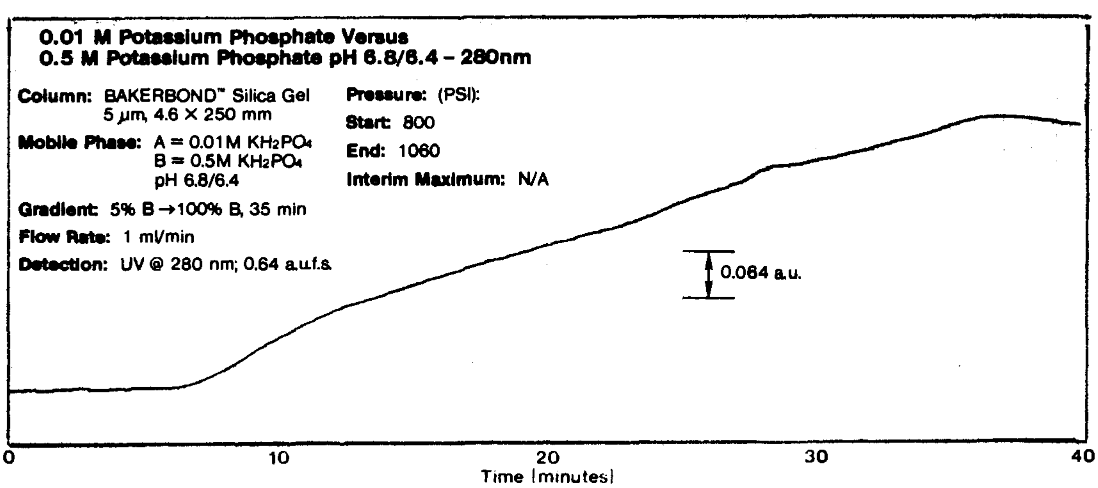
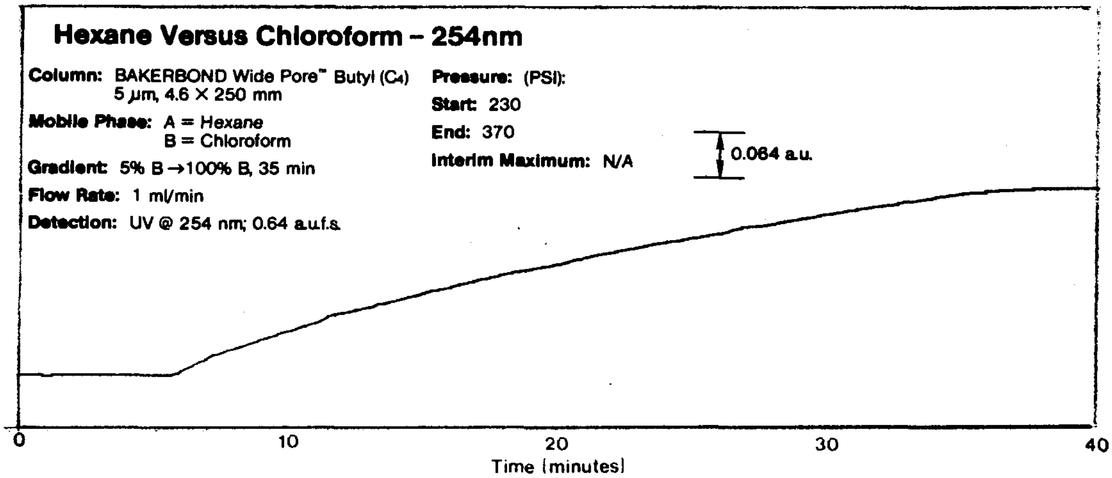


Table 16.12: Hexane vs Chloroform *(56)*



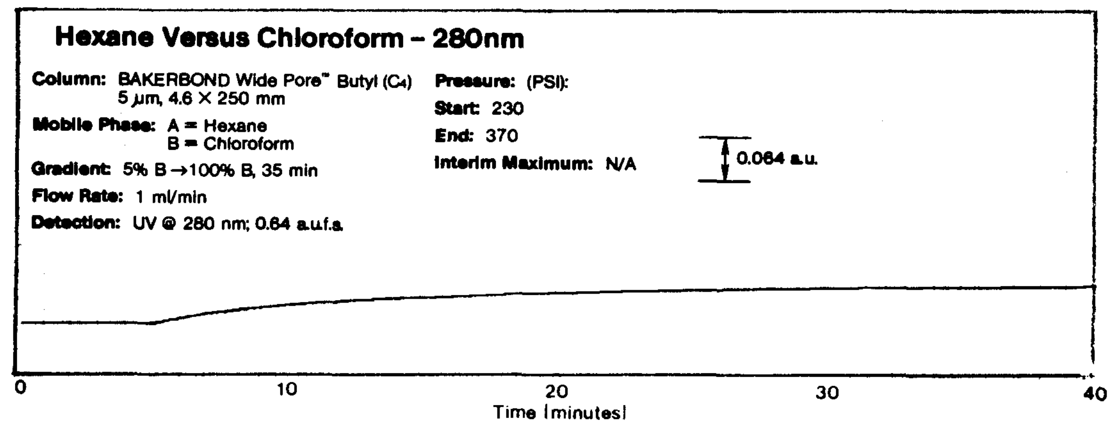


Table 16.13: Hexane vs Methylene Chloride *(56)*

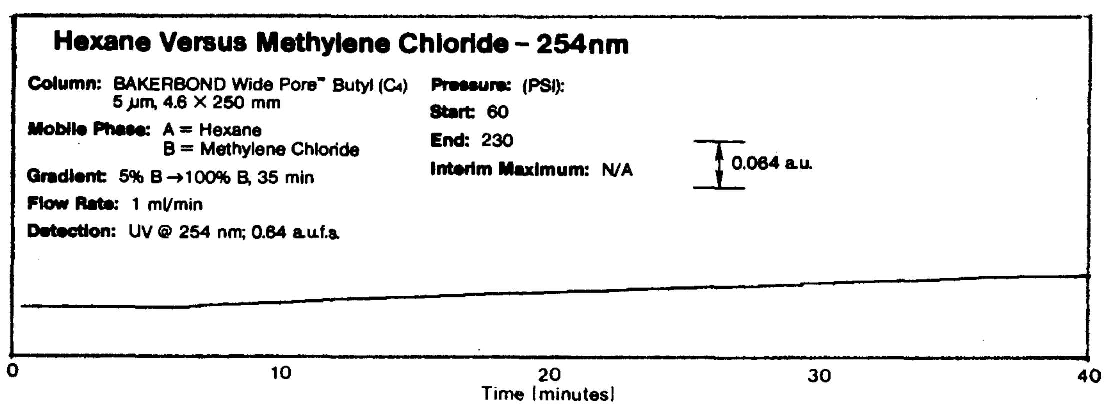
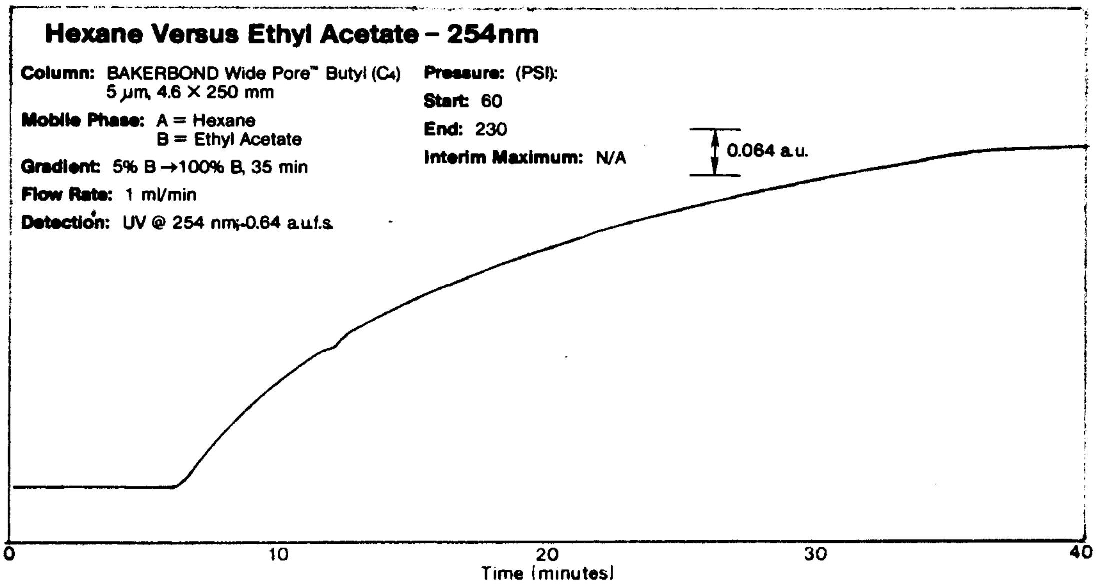


Table 16.14: Hexane vs Ethyl Acetate *(56)*



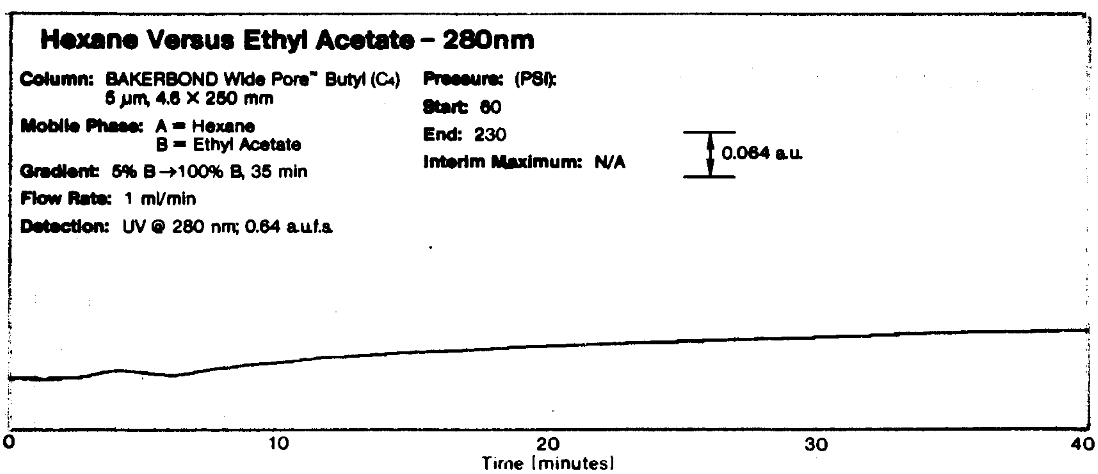
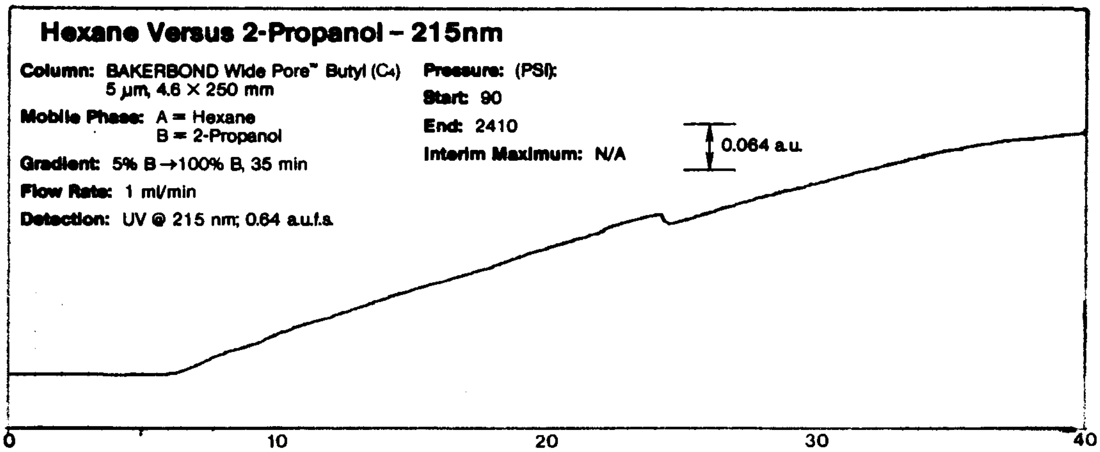


Table 16.15: Hexane vs 2-Propanol *(56)*



(continued)

Table 16.15: (continued)

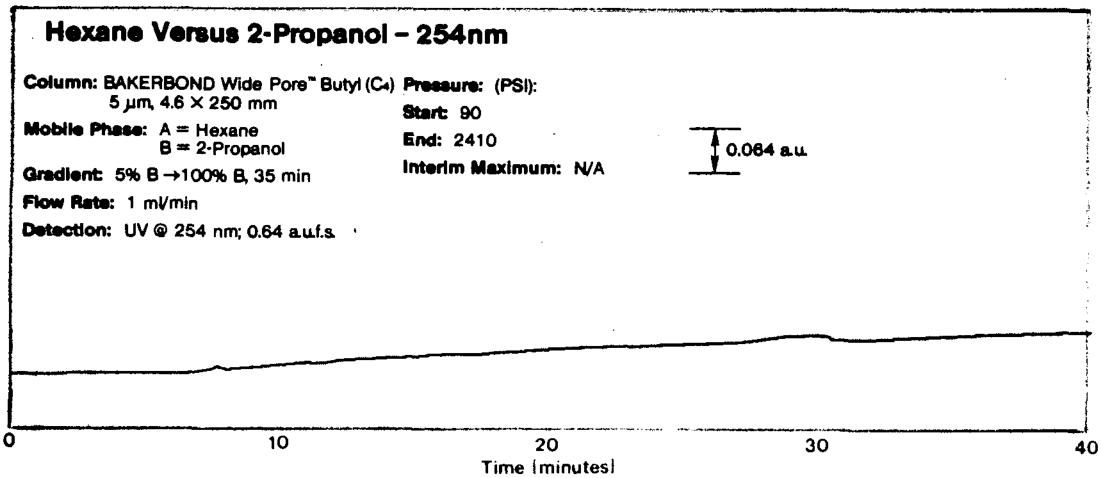
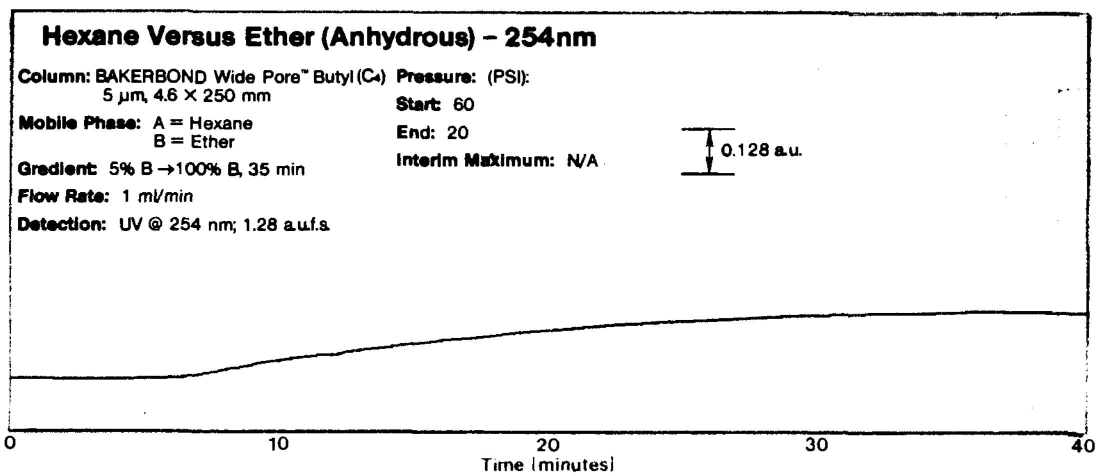


Table 16.16: Hexane vs Ether (Anhydrous) *(56)*



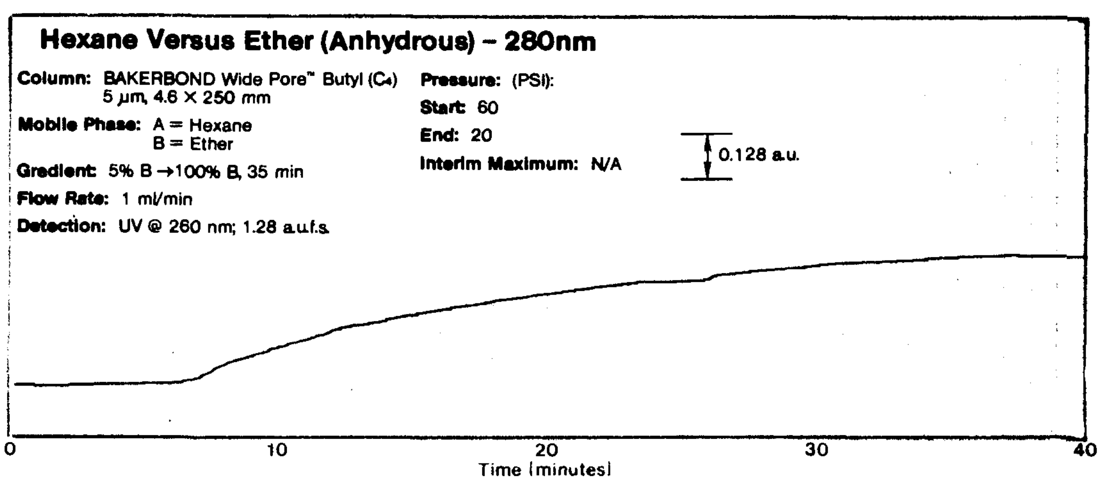
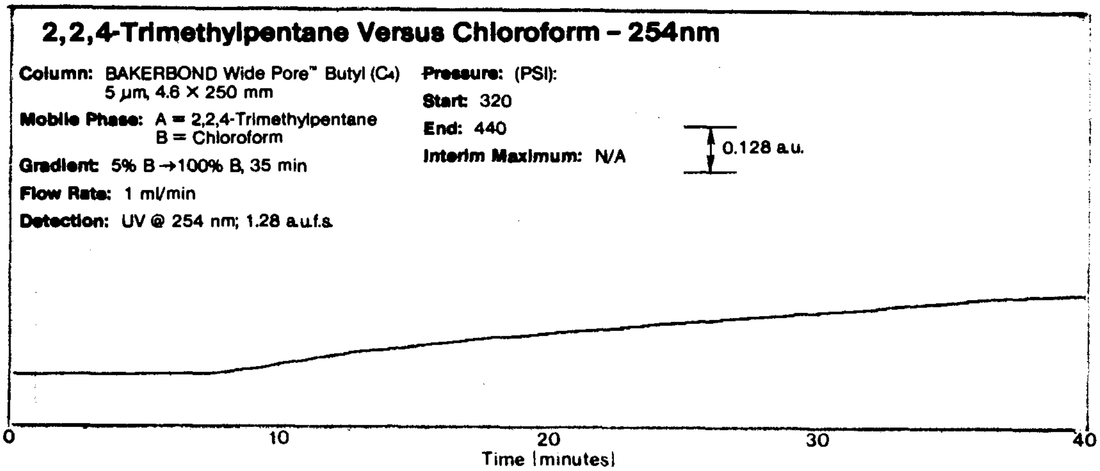


Table 16.17: 2,2,4-Trimethylpentane vs Chloroform *(56)*



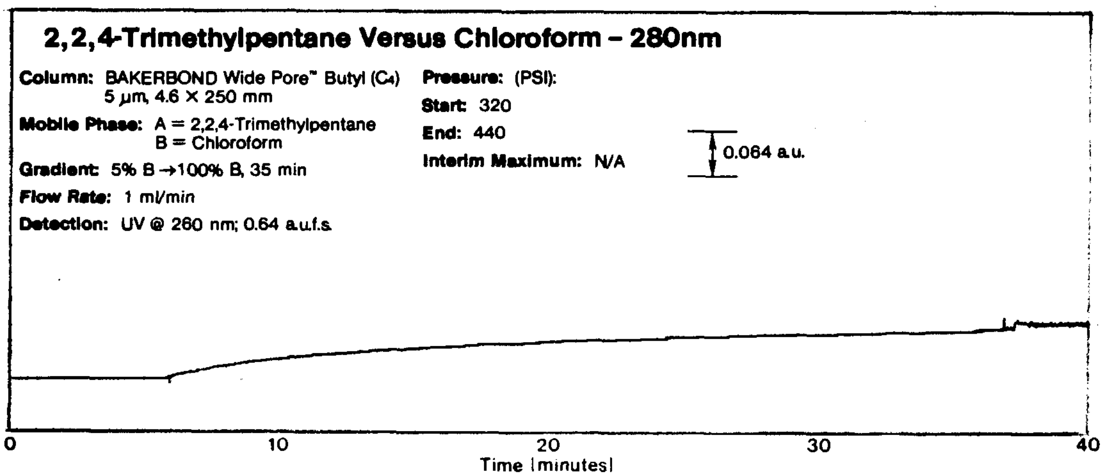


Table 16.18: 2,2,4-Trimethylpentane vs Methylene Chloride *(56)*

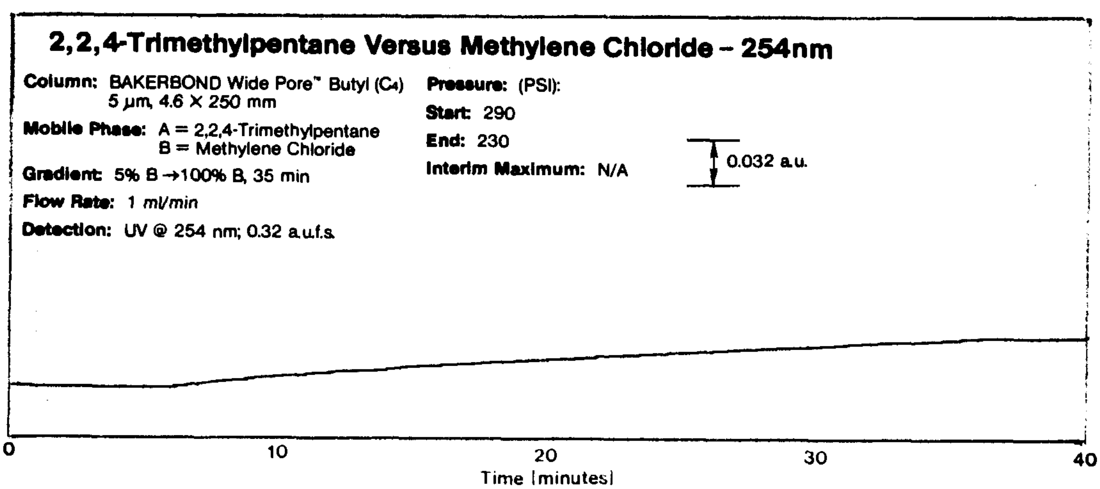
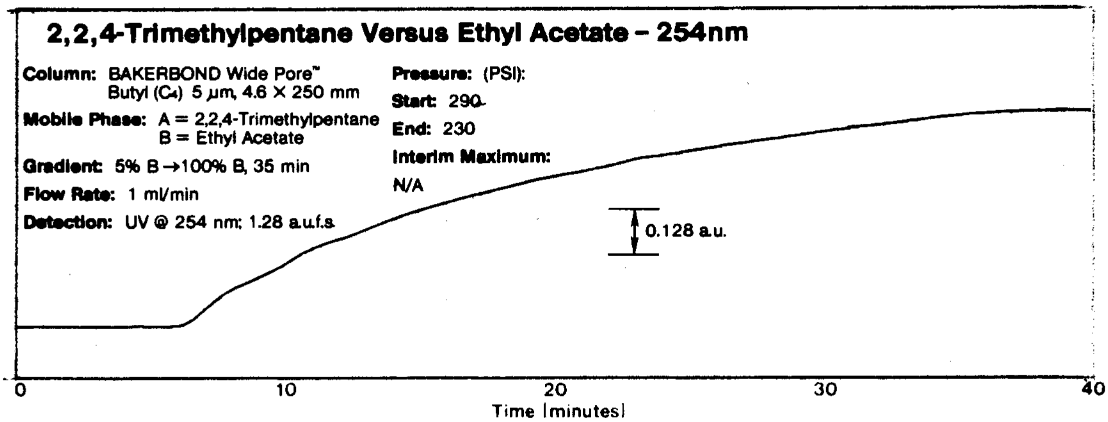


Table 16.19: 2,2,4-Trimethylpentane vs Ethyl Acetate *(56)*



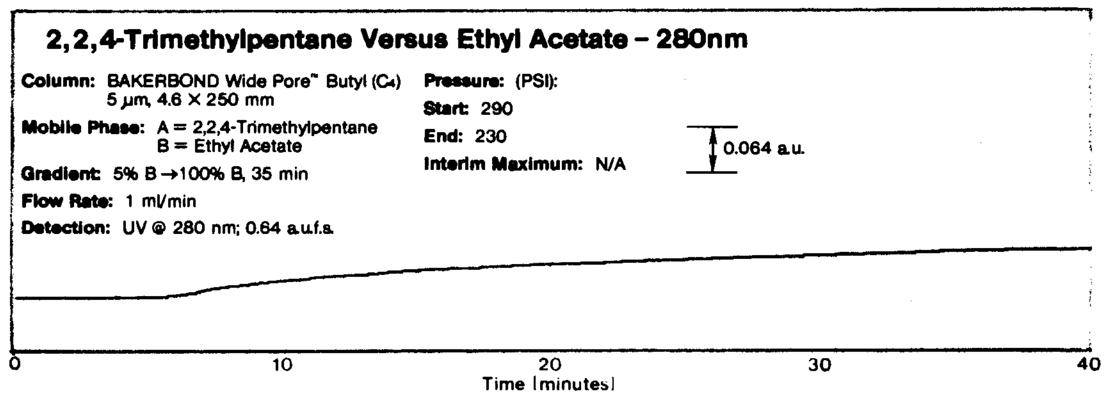
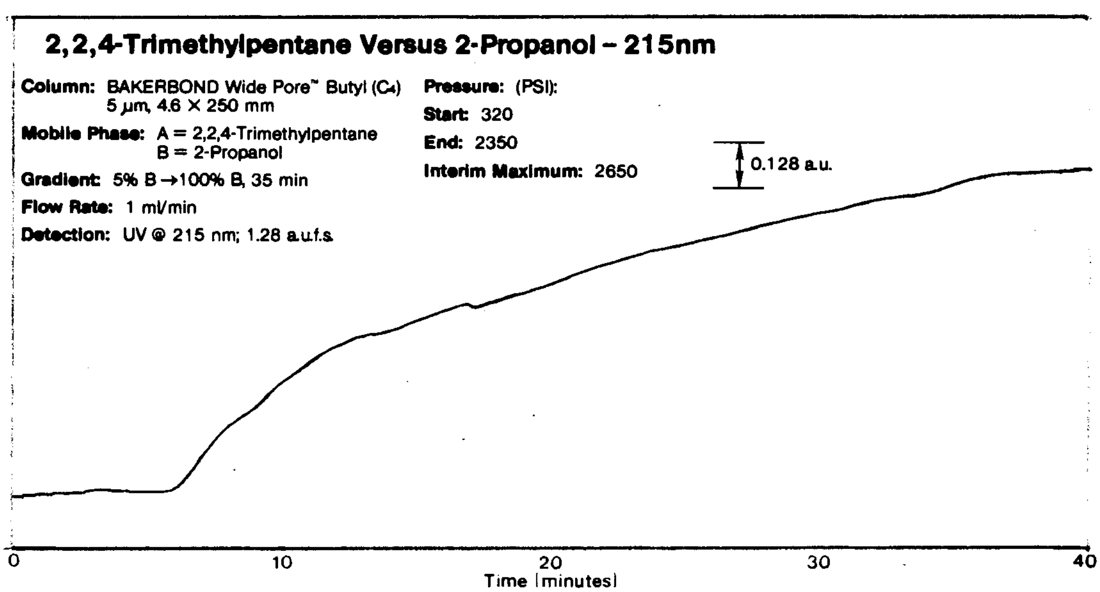


Table 16.20: 2,2,4-Trimethylpentane vs 2-Propanol *(56)*



(continued)

Table 16.20: (continued)

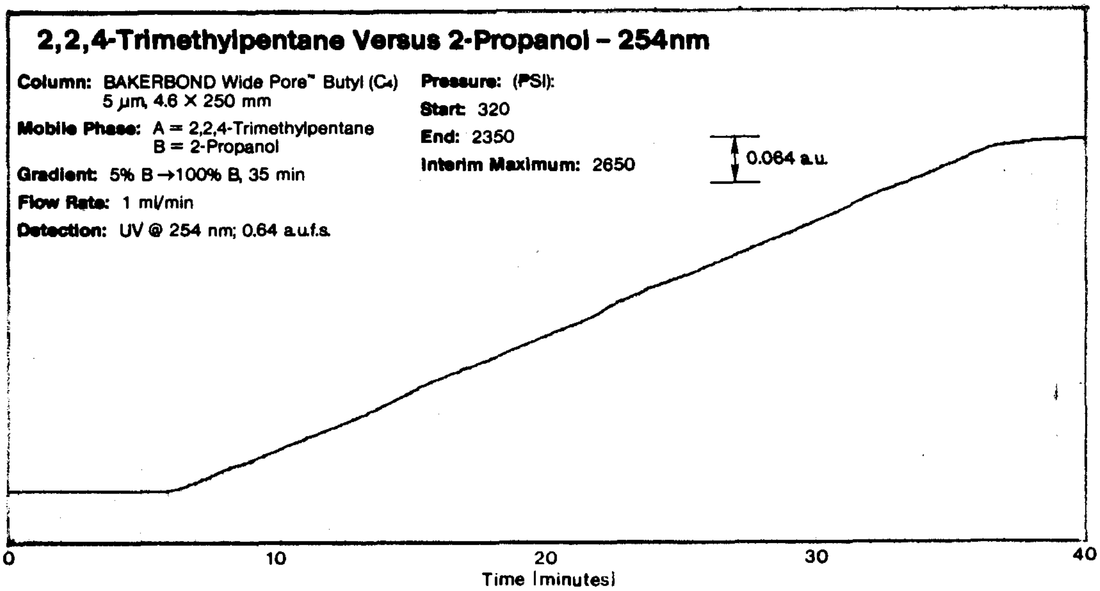


Table 16.21: Methylene Chloride vs Methanol *(56)*

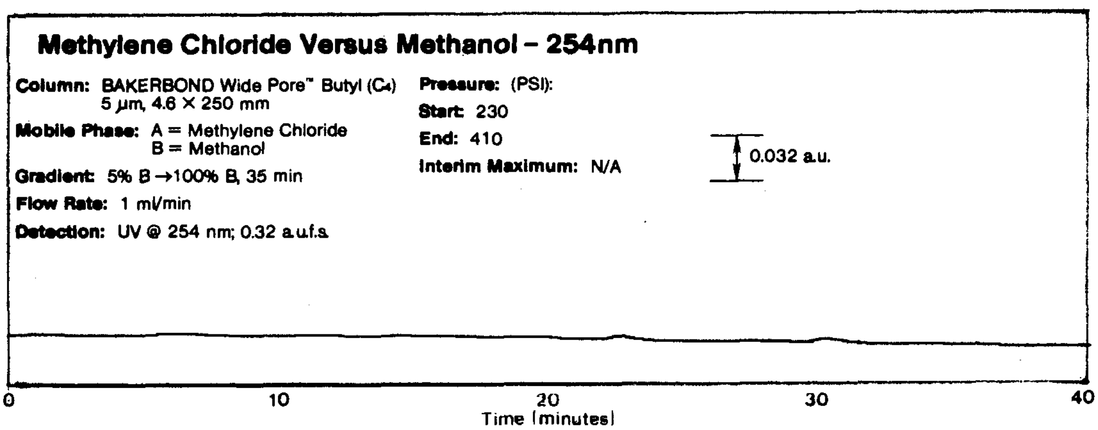


Table 16.22: Methylene Chloride vs 2-Propanol *(56)*

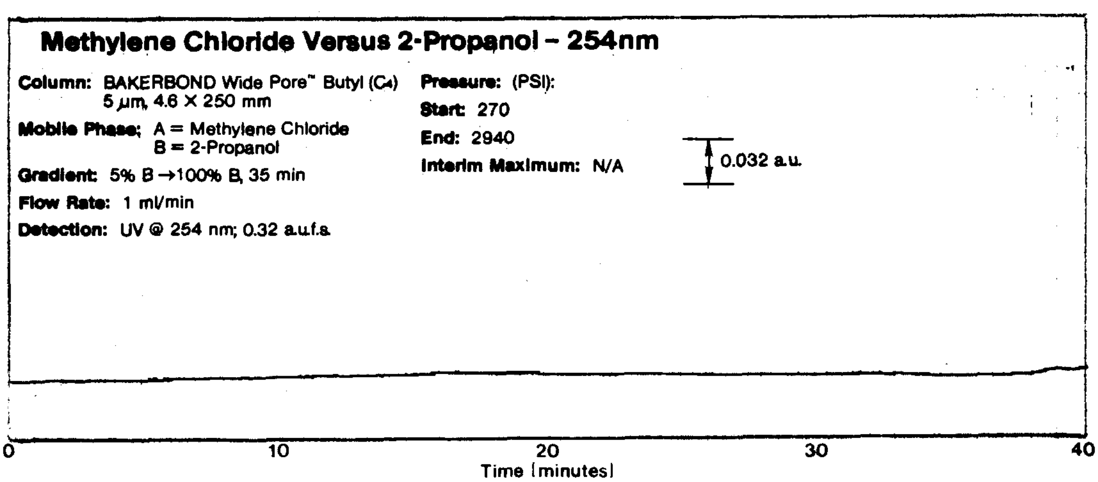
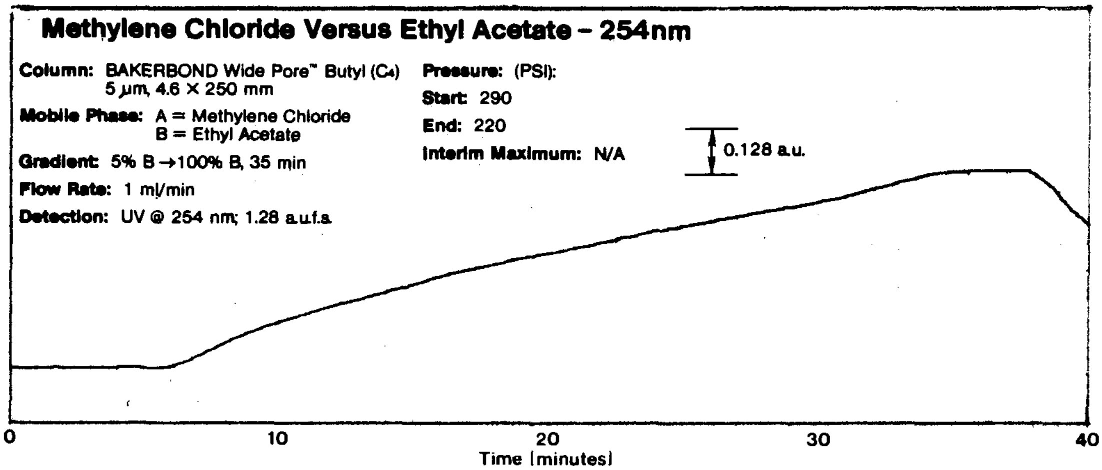


Table 16.23: Methylene Chloride vs Ethyl Acetate *(56)*



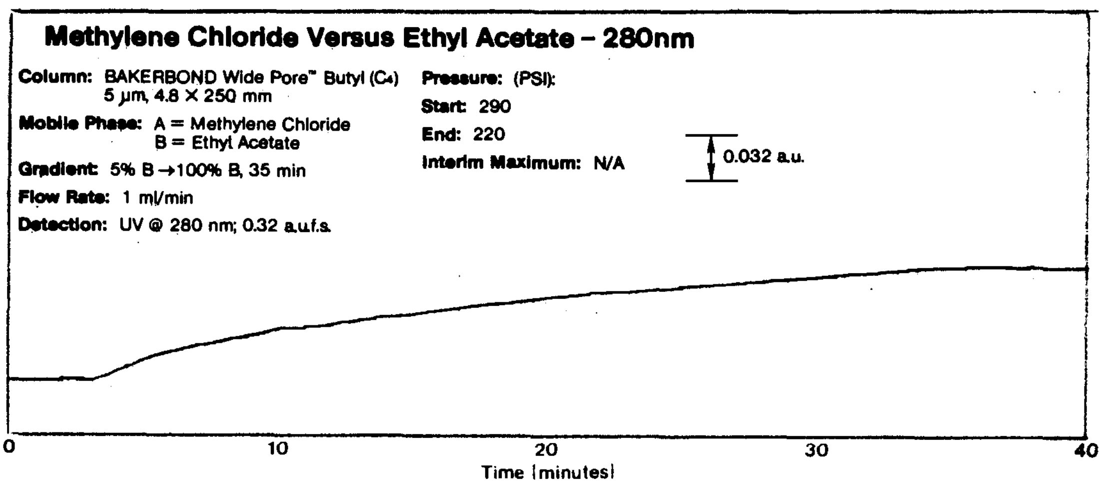
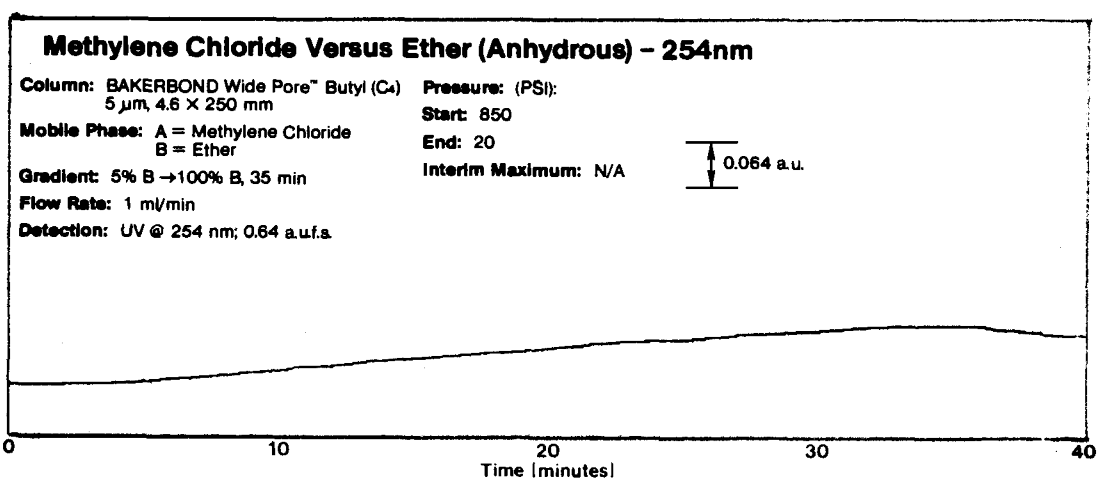
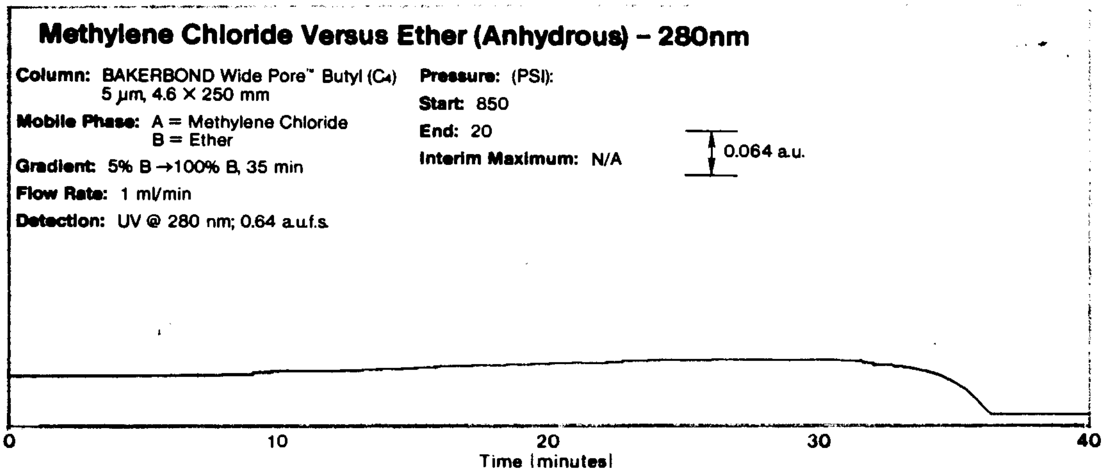


Table 16.24: Methylene Chloride vs Ether (Anhydrous) *(56)*



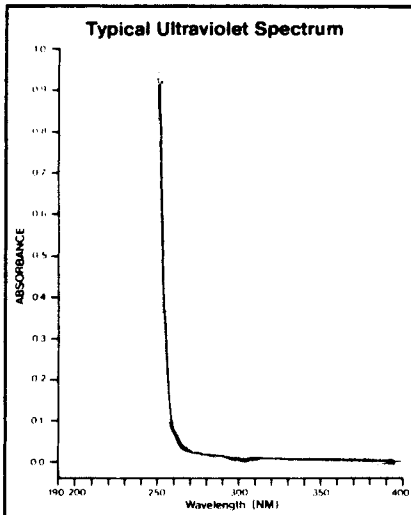
(continued)

Table 16.24: (continued)



ULTRAVIOLET SPECTRA

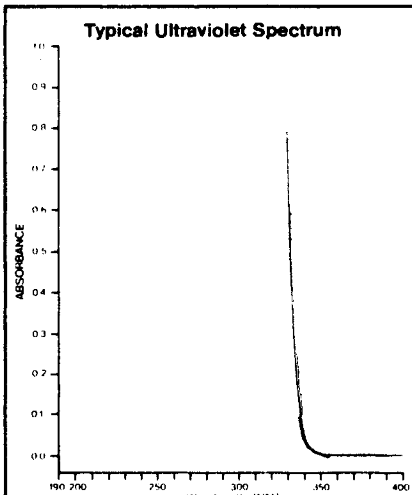
Table 16.25: Acetic Acid, Glacial *(56)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	>0.73
Polarity Index (P′):	6.2
Viscosity (cP, 25°C):	1.1
Density (g/ml):	1.049
Boiling Point (°C):	118°
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.370

Table 16.26: Acetone *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.43
Polarity Index (P′):	5.4
Viscosity (cP, 25°C):	0.30
Density (g/ml):	0.791
Boiling Point (°C):	56°
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.356

(continued)

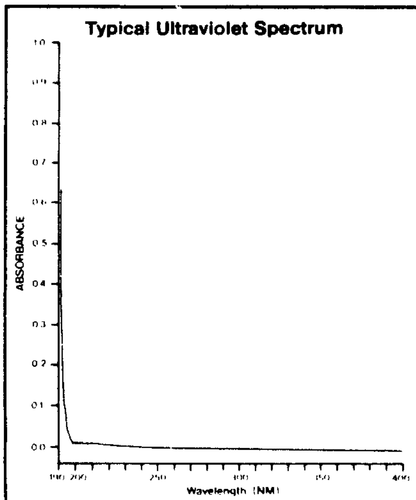
Table 16.26: (continued)

SPECIFICATIONS *(61)*
Packed under nitrogen
Water: Less than 0.50% by infrared spectroscopy
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
330	1.000
340	0.060
350	0.010
375	0.005
400	0.005

Refractive index: 1.3586 ± 0.0003 at 20°C
Boiling range: 56-57°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.27: Acetonitrile *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.50
Polarity Index (P′):	6.2
Viscosity (cP, 25°C):	0.34
Density (g/ml):	0.786
Boiling Point (°C):	82°
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.341

ACETONITRILE NON-SPECTRO *(61)*

SPECIFICATIONS
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance: Optical transparency is not controlled. For spectrophotometric applications use Acetonitrile UV.
Refractive index: 1.3440 ± 0.0006 at 20°C
Boiling range: 81-82°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide, based on a 1:1 petroleum ether extract.

(continued)

Table 16.27: (continued)

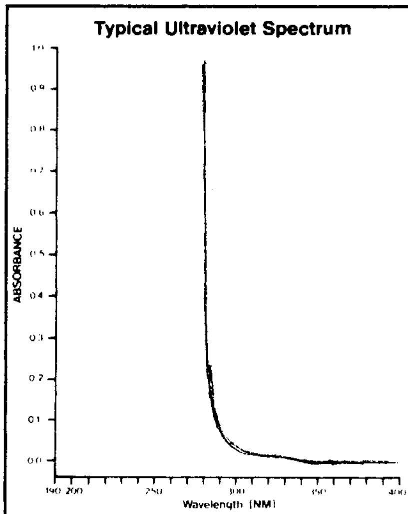
<u>ACETONITRILE UV</u> *(61)*

<u>SPECIFICATIONS</u>
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
190	1.000
200	0.050
225	0.010
250	0.005
350	0.005

Refractive index: 1.3440 ± 0.0006 at 20°C
Boiling range: 81-82°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide, based on a 1:1 petroleum ether extract.
Purity by liquid chromatography: No UV absorbing peak greater than 0.001 absorbance unit (1 cm path length) at 254 nm, or 0.005 absorbance unit at 205 nm in a gradient from 100% water to 100% acetonitrile on a 15 x 0.46 cm column with 5 uM C-18 packing. No fluorescent peak greater than that equivalent to 20 pg of benzo(a)-pyrene under the above conditions using 350 nm excitation, 450 nm emission.

Table 16.28: Benzene *(56)(61)*



Physical Data

Eluotropic Value, (ε) (on Silica):	0.27
Polarity Index (P′):	3.0
Viscosity (cP, 25 C):	0.60
Density (g/ml):	0.879
Boiling Point (C):	80
Percent Water Soluble in Solvent:	0.058%
Refractive Index (25 C):	1.498

<u>SPECIFICATIONS</u> *(61)*
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
278	1.000
300	0.020
325	0.010
350	0.005
400	0.005

Refractive index: 1.5006 ± 0.0006 at 20°C
Boiling range: 80-81°C
Residue: Less than one mg/l
Purity: Greater than 99.5% by gc analysis
Substances darkened by sulfuric acid: Passes ACS test
Color with hot sulfuric acid: Passes test (colorless)
Thiophene: Passes ACS test (limit one mg/l)
Electron capture gc: No residue peak greater than 4 ug/l as heptachlor epoxide.

Table 16.29: 2-Butanol *(61)*

SPECIFICATIONS
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
260	1.000
275	0.300
300	0.010
350	0.005
400	0.005

Refractive index: 1.3970 ± 0.0008 at 20°C
Boiling range: 99-100°C
Residue: Less than five mg/l
Purity: Greater than 98% by gc analysis

Table 16.30: n-Butyl Acetate *(61)*

SPECIFICATIONS
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
254	1.000
275	0.050
300	0.010
350	0.005
400	0.005

Refractive index: 1.3937 ± 0.0010 at 20°C
Boiling range: 124-126°C
Residue: Less than five mg/l
Purity: Greater than 99.0% by gc analysis

Table 16.31: n-Butyl Alcohol *(61)*

SPECIFICATIONS
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
215	1.000
225	0.500
250	0.040
275	0.010
300	0.005

Refractive index: 1.3990 ± 0.0004 at 20°C
Boiling range: 117-118°C
Residue: Less than five mg/l
Purity: Greater than 99.8% by gc analysis

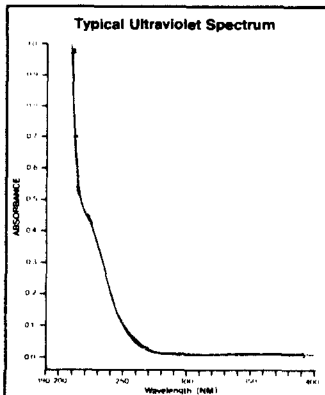
Table 16.32: n-Butyl Chloride *(61)*

SPECIFICATIONS
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
220	1.000
225	0.300
250	0.010
300	0.005
400	0.005

Refractive index: 1.4017 ± 0.0008 at 20°C
Boiling range: 78-79°C
Residue: Less than one mg/l
Chloride: Not detectable (limit 10 mg/l)
Purity: Greater than 99.5% by gc analysis

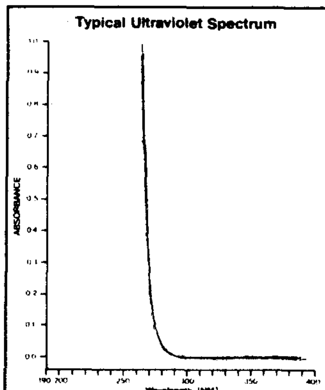
Table 16.33: tert-Butyl Methyl Ether *(56)*



Physical Data

Eluotropic Value, (ε) (on Silica):	0.29
Polarity Index (P'):	N/A
Viscosity (cP, 25 C):	0.28
Density (g/ml):	0.758
Boiling Point (C):	55.3
Percent Water Soluble in Solvent:	N/A
Refractive Index (25 C):	1.368

Table 16.34: Carbon Tetrachloride *(56)(61)*



Physical Data

Eluotropic Value, (ε) (on Silica):	0.14
Polarity Index (P'):	1.6
Viscosity (cP, 25 C):	0.90
Density (g/ml):	1.594
Boiling Point (C):	77
Percent Water Soluble in Solvent:	0.008%
Refractive Index (25 C):	1.457

(continued)

Table 16.34: (continued)

SPECIFICATIONS *(61)*
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
263	1.000
275	0.100
300	0.005
350	0.005
400	0.005

Refractive index: 1.4601 ± 0.0003 at 20°C
Boiling range: 76-77°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Substances darkened by sulfuric acid: Passes ACS test
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Infrared absorbance: C-H and C=O free. Shows no extraneous absorbance bands in the 3.1-3.6 and 5.6-6.0 micron ranges when observed in a 25 mm path length liquid cell.

Table 16.35: Chlorobenzene *(61)*

SPECIFICATIONS
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

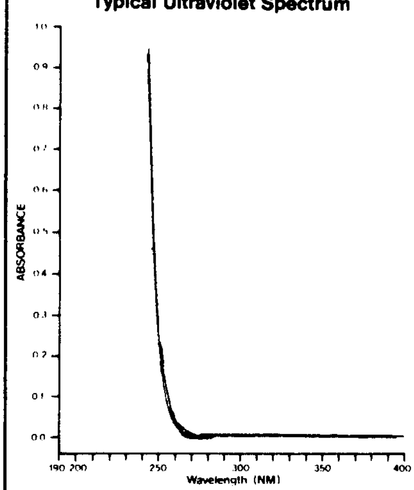
Wavelength, nm	Maximum Absorbance
287	1.000
300	0.050
325	0.040
350	0.020
400	0.005

Refractive index: 1.5249 ± 0.0007 at 20°C
Boiling range: 131-132°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis

Table 16.36: Chloroform *(56)(61)*

(Alcohol Stabilized) *(56)*

Typical Ultraviolet Spectrum

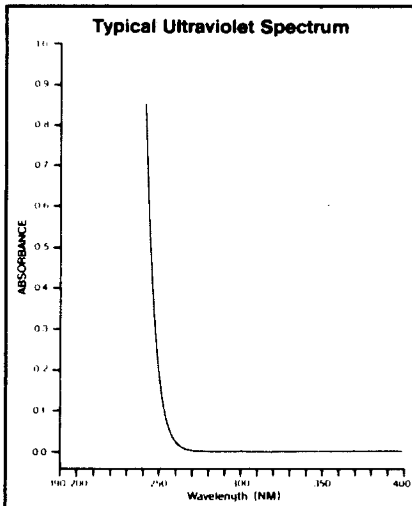


Physical Data	
Eluotropic Value, (ε°) (on Silica):	0.31
Polarity Index (P′):	4.4
Viscosity (cP, 25°C):	0.53
Density (g/ml):	1.483
Boiling Point (°C):	61
Percent Water Soluble in Solvent:	0.072%
Refractive Index (25°C):	1.443

(continued)

Table 16.36: (continued)

(Hydrocarbon Stabilized) *(56)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.26
Polarity Index (P'):	4.4
Viscosity (cP, 25°C):	0.53
Density (g/ml):	1.483
Boiling Point (°C):	61°
Percent Water Soluble in Solvent:	0.072%
Refractive Index (25°C):	1.443

(Without Ethanol) *(61)*

SPECIFICATIONS
Packed under nitrogen
Preservative: Amylene
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
245	1.000
250	0.300
275	0.005
300	0.005
400	0.005

Refractive index: 1.4457 ± 0.0003 at 20°C
Boiling range: 61-62°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis (excluding preservative)
Suitability for use in dithizone tests: Passes ACS test
Substances darkened by sulfuric acid: Passes ACS test
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Alkaline extraction: Absorbance of aqueous alkaline extract not more than 0.10 at 240 nm.
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

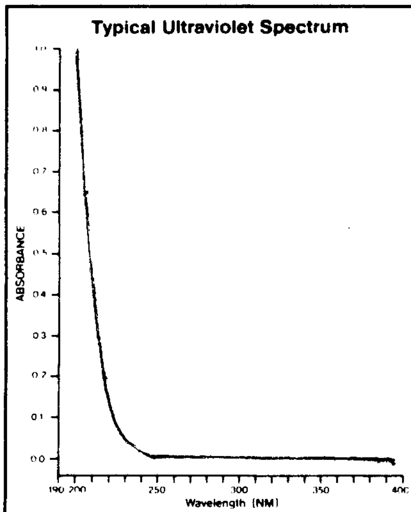
(With 1% Ethanol) *(61)*

SPECIFICATIONS
Packed under nitrogen
Contains 1% ethanol.
Preservative: Amylene
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
245	1.000
250	0.300
275	0.005
300	0.005
400	0.005

Refractive index: 1.4447 ± 0.0004 at 20°C
Boiling range: 61-62°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis (excluding preservative)
Suitability for use in dithizone tests: Passes ACS test
Substances darkened by sulfuric acid: Passes ACS test
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Alkaline extraction: Absorbance of aqueous alkaline extract not more than 0.10 at 240 nm.
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.37: Cyclohexane *(56)(61)*



Physical Data

Eluotropic Value, (ε) (on Silica):	0.03
Polarity Index (P′):	0.0
Viscosity (cP, 25°C):	0.90
Density (g/ml):	0.774
Boiling Point (°C):	81
Percent Water Soluble in Solvent:	0.012%
Refractive Index (25°C):	1.423

SPECIFICATIONS *(61)*
Water: Less than 0.01% by Karl Fischer titration

Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
200	1.000
225	0.170
250	0.020
300	0.005
400	0.005

Refractive index: 1.4240 ± 0.0020 at 20°C
Boiling range: 80-81°C
Residue: Less than one mg/l
Purity: Greater than 99.5% by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.38: Cyclopentane *(61)*

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration

Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
200	1.000
215	0.300
225	0.020
300	0.005
400	0.005

Refractive index: 1.4065 ± 0.0005 at 20°C
Boiling range: 49-50°C
Residue: Less than one mg/l
Purity: Greater than 75% cyclopentane and 99% cyclopentane and saturated C_5 hydrocarbons by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

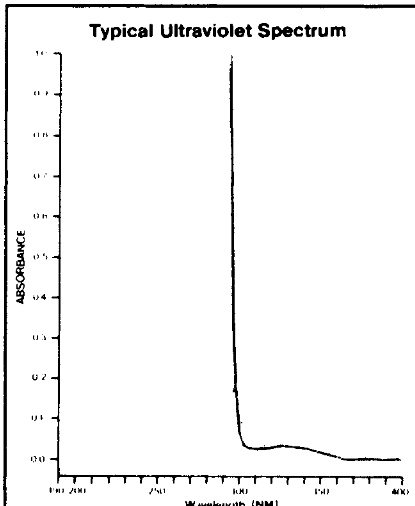
Table 16.39: Decahydronaphthalene (Decalin) *(61)*

<u>SPECIFICATIONS</u>
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance (under nitrogen):

Wavelength, nm	Maximum Absorbance
200	1.000
225	0.500
250	0.050
300	0.005
400	0.005

Refractive index: 1.4766 ± 0.0015 at 20°C
Residue: Less than 10 mg/l
Purity: Greater than 99.0% by gc analysis

Table 16.40: o-Dichlorobenzene *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	N/A
Polarity Index (P′):	N/A
Viscosity (cP, 25°C):	1.33
Density (g/ml):	1.306
Boiling Point (°C):	180.5
Percent Water Soluble in Solvent:	0.3%
Refractive Index (25°C):	1.551

<u>SPECIFICATIONS</u> *(61)*
Water: Less than 0.02% by Karl Fischer titration

Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
295	1.000
300	0.300
325	0.100
350	0.050
400	0.005

Refractive index: 1.5517 ± 0.0008 at 20°C
Residue: Less than five mg/l
Purity: Greater than 98.0% by gc analysis

Table 16.41: Diethyl Carbonate *(61)*

SPECIFICATIONS
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
256	1.000
265	0.150
275	0.050
300	0.040
400	0.010

Refractive index: 1.384 ± 0.0010 at 20°C
Boiling range: 125-126°C
Residue: Less than five mg/l
Purity: Greater than 99.0% by gc analysis

Table 16.42: Dimethyl Acetamide *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
268	1.000
275	0.300
300	0.080
350	0.005
400	0.005

Residue: Less than one mg/l
Purity: Greater than 99.5% by glc analysis
Gc impurities eluting before solvent: None greater than five mg/l

Table 16.43: Dimethyl Formamide *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
268	1.000
275	0.300
300	0.050
350	0.005
400	0.005

Residue: Less than two mg/l
Purity: Greater than 99.9% by glc analysis
Gc impurities eluting before solvent: None greater than five mg/l

Table 16.44: Dimethyl Sulfoxide *(61)*

<u>SPECIFICATIONS</u>
Packed under nitrogen
Water: Less than 0.04% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
268	1.000
275	0.500
300	0.200
350	0.020
400	0.005

Refractive index: 1.4775 ± 0.0015 at 20°C
Residue: Less than one mg/l
Purity: Greater than 99.5% by gc analysis

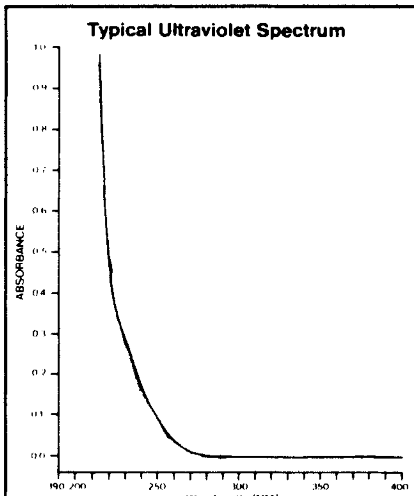
Table 16.45: 1,4-Dioxane *(61)*

<u>SPECIFICATIONS</u>
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
215	1.000
250	0.300
300	0.020
350	0.005
400	0.005

Refractive index: 1.4216 ± 0.0010 at 20°C
Boiling range: 101-102°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

Table 16.46: Ether, Anhydrous *(56)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.29
Polarity Index (P′):	2.9
Viscosity (cP, 25°C):	0.24
Density (g/ml):	0.708
Boiling Point (°C):	35
Percent Water Soluble in Solvent:	1.3%
Refractive Index (25°C):	1.350

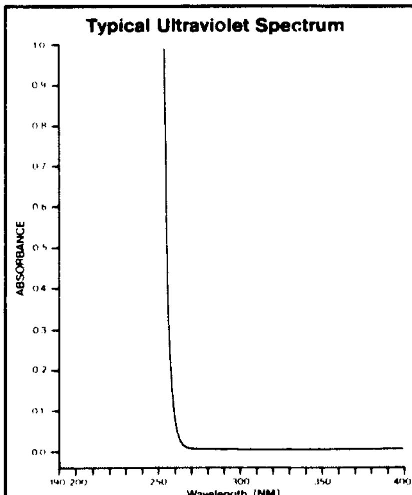
Table 16.47: 2-Ethoxyethanol *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
210	1.000
225	0.500
250	0.200
300	0.005
400	0.005

Refractive index: 1.4074 ± 0.0005 at 20°C
Boiling range: 134-136°C
Residue: Less than one mg/l
Purity: Greater than 99.5% by gc analysis
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

Table 16.48: Ethyl Acetate *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.45
Polarity Index (P′):	4.3
Viscosity (cP, 25°C):	0.43
Density (g/ml):	0.900
Boiling Point (°C):	77
Percent Water Soluble in Solvent:	9.8%
Refractive Index (25°C):	1.370

SPECIFICATIONS *(61)*
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
256	1.000
275	0.050
300	0.030
325	0.005
350	0.005

Refractive index: 1.3721 ± 0.0003 at 20°C
Boiling range: 77-78°C
Residue: Less than one mg/l
Purity: Greater than 99.5% by gc analysis. A special grade free of trace aldehyde, ketone, acid, and alcohol (less than 0.005A at 275 nm) is available at extra cost.
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.48: (continued)

ETHYL ACETATE - Ketone Free

Purified for applications requiring solvent free of trace aldehyde, ketone, acid or alcohol.

SPECIFICATIONS
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
256	1.000
275	0.005
300	0.005

Refractive index: 1.3721 ± 0.0003 at 20°C
Boiling range: 77-78°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis.
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.
Color with sulfuric acid: Passes ACS test
Substances reducing permanganate: Passes 24 hour test

Table 16.49: Ethylene Dichloride *(61)*

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
228	1.000
240	0.300
250	0.100
300	0.005
400	0.005

Refractive index: 1.4444 ± 0.0006 at 20°C
Boiling range: 83-84°C
Residue: Less than one mg/l
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Purity: Greater than 99.9% by gc analysis

Table 16.50: Ethyl Ether *(61)*

ETHYL ETHER
WITH 2% ETHANOL

SPECIFICATIONS
Packed under nitrogen
Preservative: 2% ethanol
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
215	1.000
250	0.080
275	0.010
300	0.005
400	0.005

Refractive Index: 1.3528 ± 0.0005 at 20°C
Boiling range: 34-35°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis (excluding preservative)
Peroxides: Less than one mg/l as H_2O_2 at time of packaging
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

(continued)

Table 16.50: (continued)

ETHYL ETHER
WITHOUT PRESERVATIVE

SPECIFICATIONS
Packed under nitrogen
Contains no preservatives
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
215	1.000
250	0.080
275	0.010
300	0.005
400	0.005

Refractive Index: 1.3521 ± 0.0005 at 20°C
Boiling range: 34-35°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Peroxides: Less than one mg/l as H_2O_2 at time of packaging
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

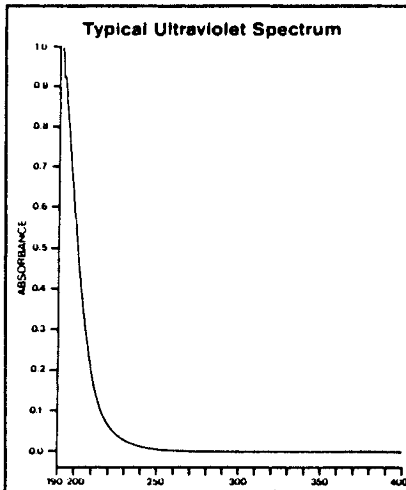
Table 16.51: GLYME *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.08% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
220	1.000
250	0.250
300	0.050
350	0.010
400	0.005

Refractive index: 1.3790 ± 0.0010 at 20°C
Boiling range: 84-85°C
Residue: Less than five mg/l
Purity: Greater than 99.5% by gc analysis
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

Table 16.52: n-Heptane *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.00
Polarity Index (P′):	0.2
Viscosity (cP, 25°C):	0.40
Density (g/ml):	0.684
Boiling Point (°C):	98
Percent Water Soluble in Solvent:	0.010%
Refractive Index (25°C):	1.385

(continued)

Table 16.52: (continued)

SPECIFICATIONS *(61)*
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
200	1.000
225	0.100
250	0.010
300	0.005
400	0.005

Refractive index: 1.3878 ± 0.0006 at 20°C
Boiling range: 98-99°C
Residue: Less than one mg/l
Purity: Greater than 96% n-heptane and 99.9% n-heptane and saturated C_7 hydrocarbons by gc analysis
Electron capture gc: No residue peak greater than 4 ug/l of heptachlor epoxide.

Table 16.53: Hexadecane *(61)*

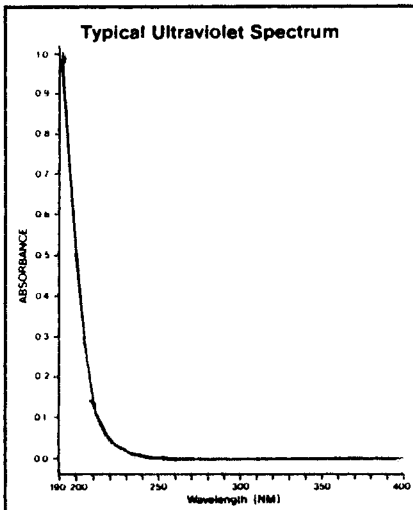
SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
190	1.000
200	0.500
250	0.020
300	0.005
400	0.005

Refractive index: 1.4340 ± 0.0006 at 20°C
Residue: Less than five mg/l
Purity: Greater than 99.9% by gc analysis

Table 16.54: Hexane *(56)(61)*

97% n-Hexane *(56)*



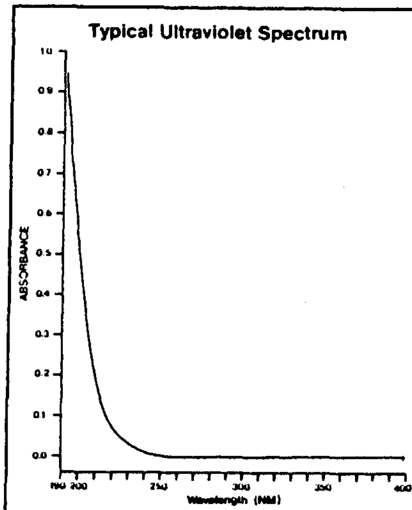
Physical Data

Eluotropic Value, (ε°) (on Silica):	0.00
Polarity Index (P′):	0.06
Viscosity (cP, 25°C):	0.30
Density (g/ml):	0.659
Boiling Point (°C):	69
Percent Water Soluble in Solvent:	0.01%
Refractive Index (25°C):	1.372

(continued)

Table 16.54: (continued)

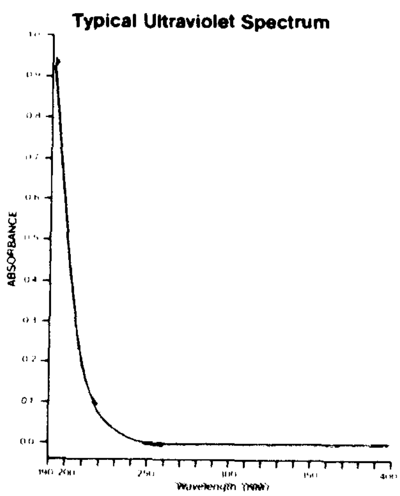
95% n-Hexane *(56)*



Physical Data

Eluotropic Value, (ε) (on Silica):	0.00
Polarity Index (P′):	0.06
Viscosity (cP, 25 C):	0.30
Density (g/ml):	0.659
Boiling Point (C):	69
Percent Water Soluble in Solvent:	0.01%
Refractive Index (25 C):	1.372

85% n-Hexane *(56)*



Physical Data

Eluotropic Value, (ε) (on Silica):	0.00
Polarity Index (P′):	0.06
Viscosity (cP, 25 C):	0.30
Density (g/ml):	0.659
Boiling Point (C):	69
Percent Water Soluble in Solvent:	0.01%
Refractive Index (25 C):	1.372

Hexane Non-Spectro *(61)*

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance: Optical transparency is not controlled. For spectrophotometric applications use Hexane UV.
Refractive index: 1.3770 ± 0.0020 at 20°C
Boiling range: 68-69°C
Residue: Less than one mg/l
Benzene: Less than 10mg/l
Purity: Greater than 85% n-hexane and 99.5% n-hexane and saturated C_6 hydrocarbons by glc analysis.
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

(continued)

Table 16.54: (continued)

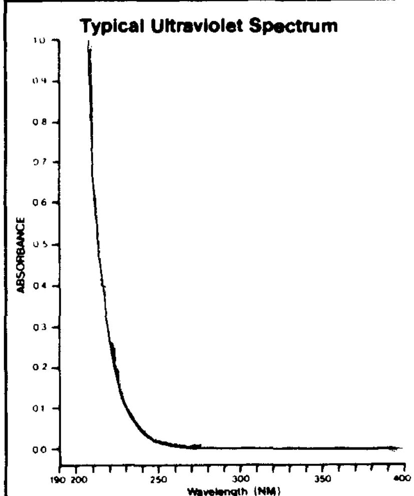
Hexane UV *(61)*

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
195	1.000
225	0.050
250	0.010
275	0.005
300	0.005

Refractive index: 1.3770 ± 0.0020 at 20°C
Residue: Less than one mg/l
Benzene: Less than one mg/l
Purity: Greater than 85% n-hexane and 99.9% n-hexane and saturated C_6 hydrocarbons by glc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.55: Isobutyl Alcohol *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.54
Polarity Index (P′):	3.0
Viscosity (cP, 25°C):	4.70
Density (g/ml):	0.802
Boiling Point (°C):	108°
Percent Water Soluble in Solvent:	N/A
Refractive Index (25°C):	1.384

SPECIFICATIONS *(61)*
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
220	1.000
250	0.050
275	0.030
300	0.020
400	0.010

Refractive index: 1.3959 ± 0.0011 at 20°C
Boiling range: 108-109°C
Residue: Less than five mg/l
Purity: Greater than 99.0% by gc analysis

Table 16.56: Iso-Octane (2,2,4-Trimethylpentane) *(61)*

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
215	1.000
225	0.100
250	0.020
300	0.005
400	0.005

Refractive index: 1.3915 ± 0.0008 at 20°C
Boiling range: 99-100°C
Residue: Less than one mg/l
Purity: Greater than 99.0% by gc analysis
Halomethanes: Less than one ppb available on special order
Electron capture gc: No residue peaks greater than 4 ug/l as heptachlor epoxide.

Table 16.57: Isopropyl Alcohol *(61)*

SPECIFICATIONS
Water: Less than 0.06% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
205	1.000
225	0.160
250	0.020
300	0.005
400	0.005

Refractive index: 1.3766 ± 0.0006 at 20°C
Boiling range: 82-83°C
Residue: Less than two mg/l
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peak greater than 4 ug/l as heptachlor epoxide.

ISOPROPYL ALCOHOL
Low Water

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
205	1.000
225	0.160
250	0.020
300	0.005
400	0.005

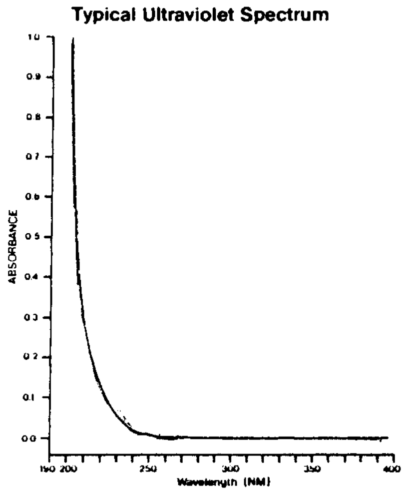
Refractive index: 1.3766 ± 0.0006 at 20°C
Boiling range: 82-83°C
Residue: Less than two mg/l
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peak greater than 4 ug/l as heptachlor epoxide.

Table 16.58: Isopropyl Myristate *(61)*

A specially purified solvent intended for sterility testing of ophthalmic ointments.

<u>SPECIFICATIONS</u>
pH of Water extract: Greater than 6.5
Appearance: Clear, colorless liquid
Infrared absorbance: Equivalent to standard

Table 16.59: Methanol *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.73
Polarity Index (P′):	6.6
Viscosity (cP, 25°C):	0.54
Density (g/ml):	0.791
Boiling Point (°C):	65
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.326

<u>SPECIFICATIONS</u> *(61)*
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
205	1.000
225	0.160
250	0.020
300	0.005
400	0.005

Refractive index: 1.3284 ± 0.0004 at 20°C
Boiling range: 64-65°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.
Purity by liquid chromatography: No UV absorbing peak greater than 0.005 absorbance unit (1 cm path length) at 254 nm in a gradient from 100% water to 100% methanol on a 15 x 0.46 cm column with 5 uM C-18 packing. No fluorescent peak greater than that equivalent to 20 pg of benzo(<u>a</u>)pyrene under the above conditions using 350 nm excitation, 450 nm emission.

<u>METHANOL</u>
<u>For Purge and Trap Analysis</u>

<u>SPECIFICATIONS</u> *(61)*
Water: Less than 0.05% by Karl Fischer titration
Refractive index: 1.3284 ± 0.0004 at 20°C
Boiling range: 64-65°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Volatile Organics: Suitable for GC-MS analysis of volatile organics in water and soil/sediment samples according to the EPA purge and trap Methods 601, 624, and 8240 (2-Butanone: less than 10 ug/l).

Table 16.60: 2-Methoxyethanol *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.08% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
210	1.000
250	0.130
275	0.030
300	0.005
400	0.005

Refractive index: 1.4020 ± 0.0010 at 20°C
Boiling range: 123-124°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Suitability for use in ninhydrin assay: Passes test
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

Table 16.61: 2- Methoxyethyl Acetate *(61)*

SPECIFICATIONS
Packed under nitrogen
Preservative: Available with or without 0.1% para-methoxyphenol
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
254	1.000
275	0.150
300	0.050
350	0.005
400	0.005

Refractive index: 1.4015 ± 0.0010 at 20°C
Boiling range: 143-144°C
Residue: Less than five mg/l
Purity: Greater than 98% by gc analysis
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

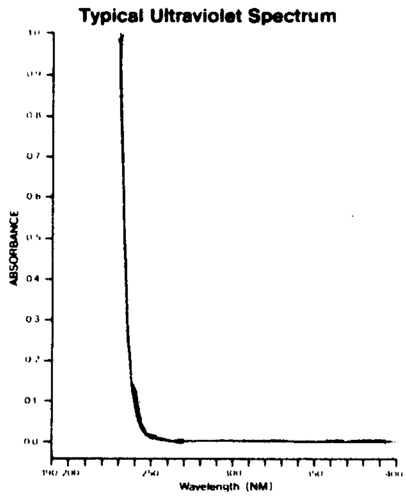
Table 16.62: Methyl t-Butyl Ether *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
210	1.000
225	0.500
250	0.100
300	0.005
400	0.005

Refractive index: 1.3690 ± 0.0010 at 20°C
Boiling range: 55-56°C
Residue: Less than one mg/l
Purity: Greater than 99.0% by gc analysis
Peroxide: Less than one mg/l as H_2O_2
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.63: Methylene Chloride *(56)(61)*



Physical Data

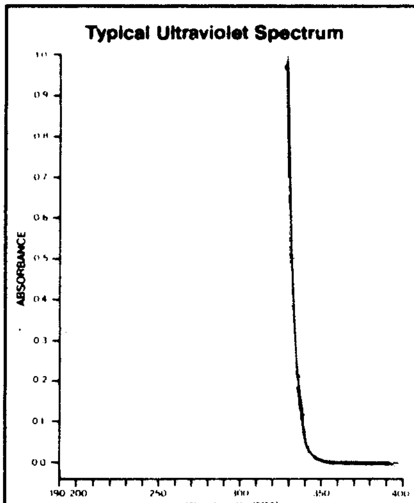
Eluotropic Value, (£) (on Silica):	0.32
Polarity Index (P′):	3.4
Viscosity (cP, 25°C):	0.41
Density (g/ml):	1.327
Boiling Point (°C):	40
Percent Water Soluble in Solvent:	0.17%
Refractive Index (25°C):	1.421

SPECIFICATIONS *(61)*
Preservative: Cyclohexene
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
233	1.000
240	0.100
250	0.010
300	0.005
400	0.005

Refractive index: 1.4241 ± 0.0005 at 20°C
Boiling range: 40-41°C
Residue: Less than one mg/l
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Purity: Greater than 99.9% by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.64: Methyl Ethyl Ketone *(56)(61)*



Physical Data

Eluotropic Value, (£) (on Silica):	0.39
Polarity Index (P′):	4.5
Viscosity (cP, 25°C):	0.38
Density (g/ml):	0.805
Boiling Point (°C):	80
Percent Water Soluble in Solvent:	23.4%
Refractive Index (25°C):	1.376

Table 16.64: (continued)

SPECIFICATIONS *(61)*
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration

Wavelength, nm	Maximum Absorbance
329	1.000
340	0.100
350	0.020
375	0.010
400	0.005

Refractive index: 1.3783 ± 0.0007 at 20°C
Boiling range: 79-80°C
Residue: Less than one mg/l
Purity: Greater than 99.5% by gc analysis

Table 16.65: Methyl Isoamyl Ketone *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
330	1.000
340	0.100
350	0.050
375	0.010
400	0.005

Refractive index: 1.4072 ± 0.0005 at 20°C
Boiling range: 142-144°C
Residue: Less than five mg/l
Purity: Greater than 99.0% by gc analysis

Table 16.66: Methyl Isobutyl Ketone *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
334	1.000
340	0.500
350	0.250
375	0.050
400	0.005

Refractive index: 1.3954 ± 0.0006 at 20°C
Boiling range: 115-116°C
Residue: Less than five mg/l
Purity: Greater than 99.0% by gc analysis

Table 16.67: Methyl n-Propyl Ketone *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
331	1.000
340	0.150
350	0.020
375	0.005
400	0.005

Refractive index: 1.3903 ± 0.0008 at 20°C
Boiling range: 101-102°C
Residue: Less than two mg/l
Purity: Greater than 90.0% methyl n-propyl ketone and greater than 99.0% methyl n-propyl ketone and methyl isobutyl ketone by gc analysis

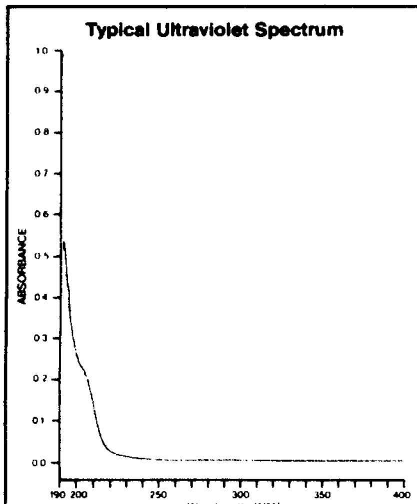
Table 16.68: N-Methylpyrrolidone *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
285	1.000
300	0.500
325	0.100
350	0.030
400	0.010

Refractive index: 1.4700 ± 0.0020 at 20°C
Purity: Greater than 99.5% by gc analysis

Table 16.69: Pentane *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.00
Polarity Index (P'):	0.0
Viscosity (cP, 25°C):	0.22
Density (g/ml):	0.626
Boiling Point (°C):	36
Percent Water Soluble in Solvent:	0.01%
Refractive Index (25°C):	1.355

Table 16.69: (continued)

SPECIFICATIONS *(61)*
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
190	1.000
200	0.600
250	0.010
300	0.005
400	0.005

Refractive index: 1.3576 ± 0.0003 at 20°C
Boiling range: 35-37°C
Residue: Less than one mg/l
Purity: Greater than 98% n-pentane and 99.9% n-pentane and saturated C_5 hydrocarbons by gc analysis
Halomethanes: Less than one ppb available on special order
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

Table 16.70: Petroleum Ether *(61)*

SPECIFICATIONS
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance: Optical transparency is not controlled. Typical ultraviolet absorption spectrum is shown for information only.
Refractive index: 1.3650 ± 0.0050 at 20°C
Boiling range: 30-60°C
Residue: Less than one mg/l
Purity: Greater than 99% total pentane and hexane isomers by gc analysis
Electron capture gc: No residue peaks greater than 10 ng/l as heptachlor epoxide.

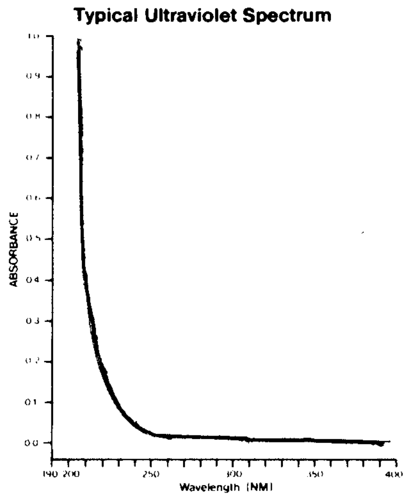
Table 16.71: beta-Phenethylamine *(61)*

SPECIFICATIONS
Packed under nitrogen
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
285	1.000
300	0.300
325	0.100
350	0.050
400	0.005

Purity: Greater than 98% by gc analysis

Table 16.72: 2-Propanol *(56)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.63
Polarity Index (P′):	4.3
Viscosity (cP, 25°C):	1.9
Density (g/ml):	0.785
Boiling Point (°C):	82
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.384

Table 16.73: n-Propyl Alcohol *(61)*

SPECIFICATIONS
Water: Less than 0.05% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
210	1.000
225	0.500
250	0.050
300	0.005
400	0.005

Refractive index: 1.3849 ± 0.0008 at 20°C
Boiling range: 97-98°C
Residue: Less than three mg/l
Purity: Greater than 99.5% by gc analysis

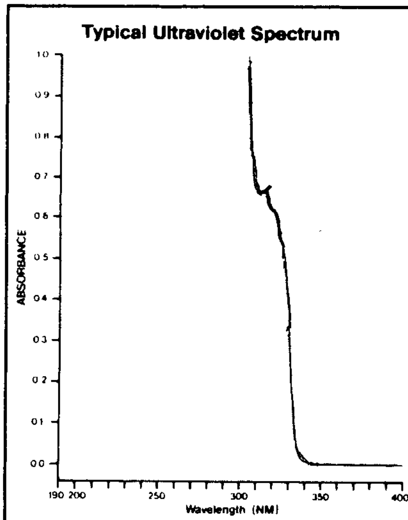
Table 16.74: Propylene Carbonate *(61)*

SPECIFICATIONS
Water: Less than 0.04% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
280	1.000
300	0.500
350	0.050
375	0.030
400	0.020

Refractive index: 1.4212 ± 0.0008 at 20°C
Residue: Less than five mg/l
Purity: Greater than 99% by gc analysis

Table 16.75: Pyridine *(56)(61)*

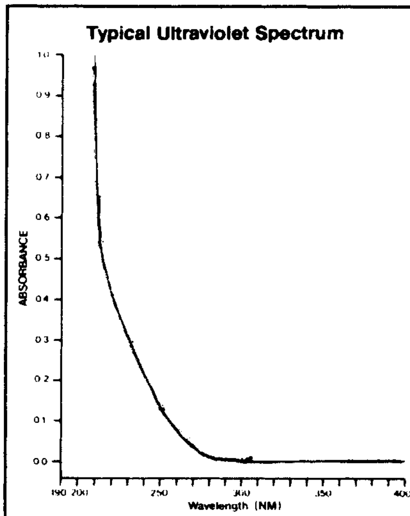


Physical Data

Eluotropic Value, (ε°) (on Silica):	0.55
Polarity Index (P′):	5.3
Viscosity (cP, 25°C):	0.88
Density (g/ml):	0.98
Boiling Point (°C):	115°
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.507

SPECIFICATIONS *(61)*
Packed under nitrogen
Water: Less than 0.05% by Karl Fischer titration
Primary and secondary amines by ninhydrin test: Less than 10 ppm
Refractive index: 1.5093 ± 0.0008 at 20°C
Boiling range: 115-116°C
Residue: Less than two mg/l
Purity: Greater than 99.8% by gc analysis

Table 16.76: Tetrahydrofuran *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.35
Polarity Index (P′):	4.2
Viscosity (cP, 25°C):	0.46
Density (g/ml):	0.881
Boiling Point (°C):	66°
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	1.405

(continued)

Table 16.76: (continued)

TETRAHYDROFURAN NON-SPECTRO *(61)*

SPECIFICATIONS
Packed under nitrogen
Preservative: 250 mg/l butylated hydroxytoluene.
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance: Optical transparency is not controlled. For spectrophotometric applications use Tetrahydrofuran UV.
Refractive index: 1.4070 ± 0.0005 at 20°C
Boiling range: 66-67°C
Purity: Greater than 99.9% by gc analysis
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

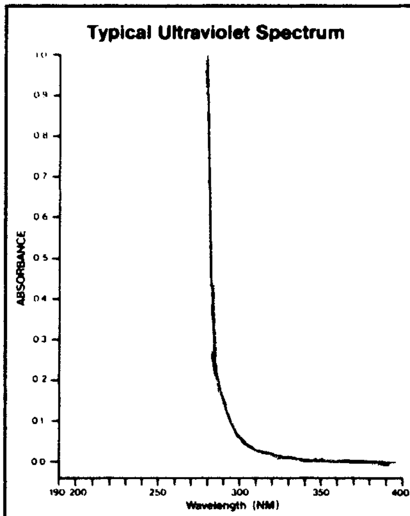
TETRAHYDROFURAN UV *(61)*

SPECIFICATIONS
Packed under nitrogen
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
212	1.000
250	0.180
300	0.020
350	0.005
400	0.005

Refractive index: 1.4070 ± 0.0005 at 20°C
Boiling range: 66-67°C
Residue: Less than one mg/l
Purity: Greater than 99.9% by gc analysis
Peroxides: Less than two mg/l as H_2O_2 at time of packaging

Table 16.77: Toluene *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.22
Polarity Index (P′):	2.4
Viscosity (cP, 25°C):	0.55
Density (g/ml):	0.867
Boiling Point (°C):	110°
Percent Water Soluble in Solvent:	0.046%
Refractive Index (25°C):	1.494

(continued)

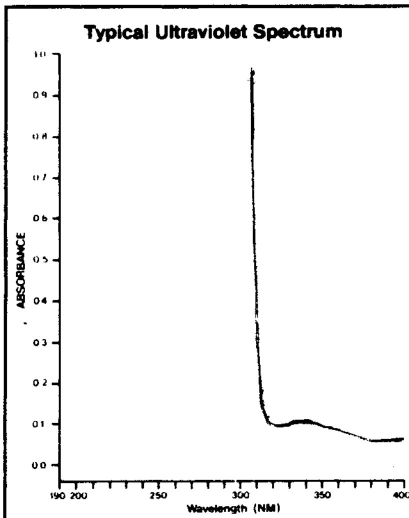
Table 16.77: (continued)

SPECIFICATIONS *(61)*
Water: Less than 0.03% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
284	1.000
300	0.120
325	0.020
350	0.005
400	0.005

Refractive index: 1.4967 ± 0.0004 at 20°C
Boiling range: 110-111°C
Residue: Less than one mg/l
Benzene: Less than 500 mg/l
Purity: Greater than 99.8% by gc analysis
Electron capture gc: No residue peak greater than 4 ug/l as heptachlor epoxide.

Table 16.78: 1,2,4-Trichlorobenzene *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	N/A
Polarity Index (P′):	N/A
Viscosity (cP, 25°C):	N/A
Density (g/ml):	1.45
Boiling Point (°C):	215°
Percent Water Soluble in Solvent:	0.02%
Refractive Index (25°C):	1.572

SPECIFICATIONS *(61)*
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
308	1.000
310	0.500
350	0.050
375	0.010
400	0.005

Refractive index: 1.5716 ± 0.0005 at 20°C
Purity: Greater than 98.0% by gc analysis
Particulate matter: Filtered through a 0.5 micron filter
Residue: Less than 10 mg/l

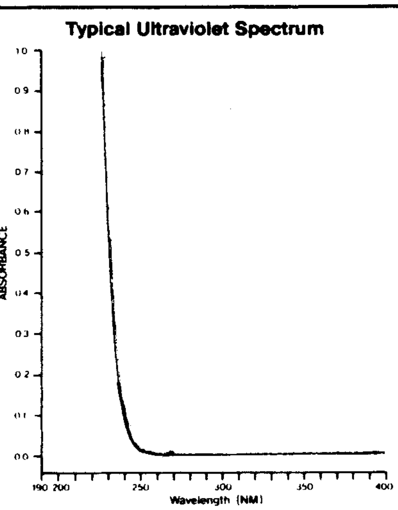
Table 16.79: Trichloroethylene *(61)*

SPECIFICATIONS
Preservative: 1,2-Butylene oxide
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
273	1.000
300	0.100
325	0.080
350	0.060
400	0.060

Refractive index: 1.4767 ± 0.0008 at 20°C
Boiling range: 86-87°C
Residue: Less than one mg/l
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Purity: Greater than 99% by gc analysis

Table 16.80: 1,1,2-Trichlorotrifluoroethane *(56)(61)*



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.02
Polarity Index (P′):	2.00
Viscosity (cP, 25°C):	0.4
Density (g/ml):	1.57
Boiling Point (°C):	48
Percent Water Soluble in Solvent:	N/A
Refractive Index (25°C):	1.267

SPECIFICATIONS *(61)*
Water: Less than 0.01% by Karl Fischer titration
Ultraviolet absorbance:

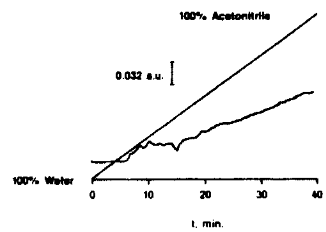
Wavelength, nm	Maximum Absorbance
231	1.000
250	0.050
300	0.005
350	0.005
400	0.005

Refractive index: 1.3583 ± 0.0003 at 20°C
Boiling range: 47-48°C
Residue: Less than one mg/l
Acidity: Not detectable (limit one mg/l as HCl)
Chloride: Not detectable (limit 10 mg/l)
Purity: Greater than 99.5% by gc analysis
Infrared absorbance: C-H free. Shows no extraneous absorbance bands in the 3.1-3.6 micron range when observed in a 25mm path length liquid cell.

Table 16.81: Trifluoroacetic Acid *(56)(61)*

Typical Actual Lot Chromatogram

Gradient Test Conditions
Column: BAKERBOND® Wide-Pore C_{18}, 4.6 x 250mm, preconditioned with 30-mL of 1% (V/V) TFA in acetonitrile
Mobile Phase: A = 0.1% TFA in H_2O
B = 0.1% TFA in CH_3CN
Gradient: 100%A → 100%B, 40-min
Flow Rate: 1-mL/min
Detection: UV @ 215; 0.64 - aufs
Sample Enrichment: 30mL applied at 1-mL/min



Physical Data

Eluotropic Value, (ε°) (on Silica):	N/A
Polarity Index (P'):	N/A
Viscosity (cP, 25°C):	N/A
Density (g/ml):	1.535
Boiling Point (°C):	72.4
Percent Water Soluble in Solvent:	Miscible
Refractive Index (25°C):	N/A

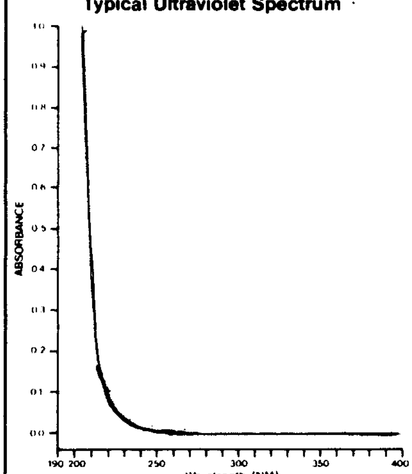
SPECIFICATIONS *(61)*
Water: Less than 0.05%
Ultraviolet absorbance (0.1% solution in water):

Wavelength, nm	Maximum Absorbance
210	1.000
230	0.150
250	0.010
300	0.005

Purity: Greater than 99.9% by titration

Table 16.82: Trimethylpentane *(56)*

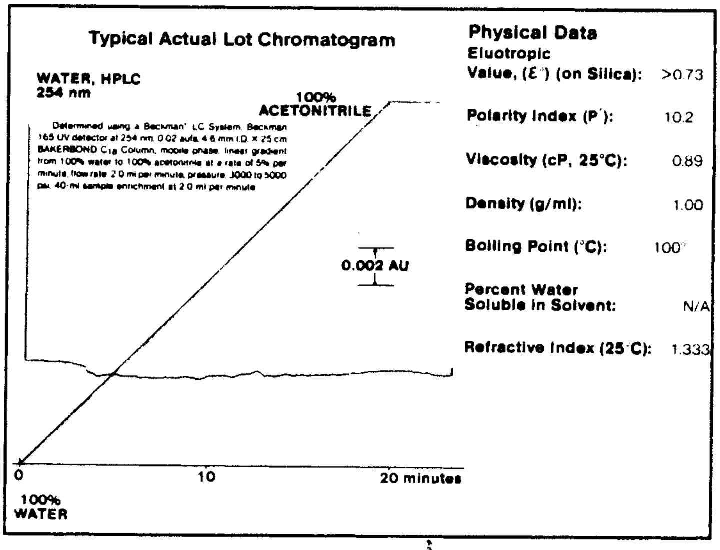
Typical Ultraviolet Spectrum



Physical Data

Eluotropic Value, (ε°) (on Silica):	0.01
Polarity Index (P'):	0.1
Viscosity (cP, 25°C):	0.47
Density (g/ml):	0.690
Boiling Point (°C):	99
Percent Water Soluble in Solvent:	0.011%
Refractive Index (25°C):	1.389

Table 16.83: Water *(56)(61)*



HIGH PURITY WATER *(61)*

SPECIFICATIONS
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
190	0.010
200	0.010
250	0.005
300	0.005
400	0.005

Refractive index: 1.3330 ± 0.0010 at 20°C
Residue: Less than one mg/l
Purity by liquid chromatography: No UV absorbing peak greater than 0.001 absorbance unit (1 cm path length) at 254 nm, or 0.005 absorbance unit at 205 nm in a gradient from 100% water to 100% acetonitrile on a 15 x 0.46 cm C-18 column with 5 uM packing after an initial loading of 20 mL water. No fluorescent peak greater than that equivalent to 20 pg of benzo(a)pyrene under the above conditions using 350 nm excitation, 450 nm emission.

Table 16.84: ortho-Xylene *(61)*

SPECIFICATIONS
Water: Less than 0.02% by Karl Fischer titration
Ultraviolet absorbance:

Wavelength, nm	Maximum Absorbance
288	1.000
300	0.200
325	0.050
350	0.010
400	0.005

Refractive index: 1.5050 ± 0.0010 at 20°C
Boiling range: 144-145°C
Residue: Less than five mg/l
Purity: Greater than 95.0% o-xylene and 99.0% xylenes by gc analysis

Appendix—Comparative Data for Various Solvents

Physical Properties of Some Selected Solvents *(10)*

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
WATER	18.02	0.9971	25.0	1.3329	0.0	760.	100.0	78.54	1
METHANOL	32.04	0.7866	25.0	1.3265	-97.7	0.	64.7	32.70	2
ACETONITRILE	41.05	0.7766	25.0	1.3416	-43.8	0.	81.6	37.50	3
ETHYLENIMINE	43.07	0.8320	25.0	1.4123	-78.0	0.	57.0	18.30	4
ACETALDEHYDE	44.05	0.7780	20.0	1.3311	-123.0	0.	20.4	21.10	5
FORMAMIDE	45.04	1.1334	20.0	1.4475	2.6	0.	210.5	109.00	6
FORMIC ACID	46.03	1.2141	25.0	1.3694	8.3	0.	100.6	58.50	7
ETHANOL	46.07	0.7850	25.0	1.3594	-114.1	0.	78.3	24.55	8
ACRYLONITRILE	53.06	0.8004	25.0	1.3888	-83.6	0.	77.3	33.00	9
1,2-BUTADIENE	54.09	0.6760	1.0	1.4205	-136.3	0.	10.9	0.0	10
2-BUTYNE	54.09	0.6910	20.0	1.3921	-32.3	760.	27.0	0.0	11
PROPIONITRILE	55.08	0.7818	20.0	1.3681	-92.8	0.	97.4	27.20	12
PROPIONITRILE	55.08	0.7768	25.0	1.3636	-92.8	0.	97.4	27.20	13
ACROLEIN	56.06	0.8389	20.0	1.4017	-87.0	0.	52.7	0.0	14
PROPARGYL ALCOHOL	56.06	0.9450	25.0	1.4300	-51.8	0.	113.6	24.50	15
ALLYLAMINE	57.10	0.7629	20.0	1.4205	-88.2	0.	53.3	0.0	16
ACETONE	58.05	0.7900	20.0	1.3587	-94.7	0.	56.3	20.70	17
ACETONE	58.08	0.7844	25.0	1.3560	-94.7	0.	56.3	20.70	18
ALLYL ALCOHOL	58.08	0.8540	20.0	1.4135	-129.0	0.	97.0	0.0	19
2-PROPENE-1-OL	58.08	0.8421	30.0	1.4090	-129.0	0.	97.1	21.60	20
PROPIONALDEHYDE	58.08	0.7912	25.0	1.3593	-80.0	0.	48.0	18.50	21
PROPYLENE OXIDE	58.08	0.8287	20.0	1.3660	-111.9	0.	33.9	0.0	22
N-ME FORMAMIDE	59.07	0.9988	25.0	1.4300	-3.8	0.	182.5	182.40	23
ISOPROPYLAMINE	59.11	0.6821	25.0	1.3711	-95.2	0.	32.4	5.45	24
N-PROPYLAMINE	59.11	0.7173	20.0	1.3882	-83.0	0.	48.5	5.31	25
ACETIC ACID	60.05	1.0492	20.0	1.3719	16.7	0.	117.9	6.15	26
METHYL FORMATE	60.05	0.9742	20.0	1.3433	-99.0	0.	31.5	8.50	27
ETHYLENEDIAMINE	60.10	0.8859	30.0	1.4513	11.3	0.	117.3	12.90	28
PROPANOL-1	60.10	0.8038	20.0	1.3856	-126.2	0.	97.2	20.33	29
PROPANOL-1	60.10	0.7998	25.0	1.3837	-126.2	0.	97.2	20.33	30
PROPANOL-2	60.10	0.7854	20.0	1.3772	-88.0	0.	82.3	19.92	31
NITROMETHANE	61.04	1.1312	25.0	1.3796	-28.5	0.	101.2	35.87	32
2-AMINOETHANOL	61.08	1.0116	25.0	1.4521	10.5	0.	170.0	37.72	33
1,2-ETHANEDIOL	62.07	1.1135	20.0	1.4318	-13.2	0.	197.3	37.70	34
ETHANETHIOL	62.13	0.8391	20.0	1.4311	-144.4	760.	35.0	0.0	35
METHYLSULFIDE	63.13	0.8423	25.0	1.4323	-98.3	0.	37.3	6.20	36
CHLOROETHANE	64.52	0.9039	20.0	1.3790	-136.4	0.	12.3	9.45	37
3-BUTENENITRILE	67.09	0.8329	20.0	1.4060	-84.0	760.	119.0	0.0	38
TRANS-CROTONONITRILE	67.09	0.8239	20.0	1.4225	-51.5	760.	120.5	0.0	39
METHYLACRYLONITRILE	67.09	0.8001	20.0	1.4007	-35.8	0.	90.3	0.0	40
PYRROLE	67.09	0.9699	21.0	1.5002	-23.4	0.	129.8	8.13	41
FURAN	68.08	0.9378	20.0	1.4214	0.0	0.	31.4	2.94	42
1,3-PENTADIENE	68.11	0.6830	0.0	1.4280	0.0	0.	41.6	0.0	43
ISOPRENE	68.13	0.6810	20.0	1.4219	-146.0	760.	34.0	2.10	44
1,2-PENTADIENE	68.13	0.6926	20.0	1.4209	-137.3	760.	44.9	0.0	45
1,4-PENTADIENE	68.13	0.6608	20.0	1.3888	-148.3	760.	0.0	0.0	46
2,3-PENTADIENE	68.13	0.6950	20.0	1.4284	-125.7	760.	48.3	0.0	47
BUTYRONITRILE	69.11	0.7954	15.0	1.3860	-111.9	0.	117.9	20.30	48
BUTYRONITRILE	69.11	0.7865	25.0	1.3820	-111.9	0.	117.9	20.30	49
ISOBUTYRONITRILE	69.11	0.7656	25.0	1.3712	-71.5	0.	103.9	20.40	50
PROPYNOIC ACID	70.05	1.1380	20.0	1.4306	18.0	0.	144.0	0.0	51
CROTONALDEHYDE	70.09	0.8516	20.0	1.4373	-76.5	0.	104.1	0.0	52
CYCLOPENTANE	70.13	0.7454	0.0	1.4065	-93.8	0.	49.3	1.96	53
1-PENTENE	70.13	0.6405	20.0	1.3715	-165.2	0.	30.0	2.02	54
2-PENTENE	70.13	0.6545	20.0	1.3798	-138.0	0.	36.7	0.0	55
CIS-2-PENTENE	70.13	0.6556	20.0	1.3830	-151.4	0.	36.9	0.0	56
TRANS-2-PENTENE	70.13	0.6482	20.0	1.3793	-140.2	0.	36.4	0.0	57
2-METHYL-1-BUTENE	70.14	0.6504	20.0	1.3378	-137.6	760.	31.2	2.20	58
2-METHYL-2-BUTENE	70.14	0.6623	20.0	1.3874	-133.8	760.	38.6	0.0	59
2-CYANOETHANOL	71.08	1.0404	25.0	0.0	-46.0	0.	220.0	0.0	60
3-HYDROXY PROPIONITRILE	71.08	1.0588	20.0	1.4240	0.0	760.	230.0	0.0	61
LACTONITRILE	71.08	0.9877	20.0	1.4058	-40.0	0.	183.0	0.0	62
PYRROLIDINE	71.12	0.8520	22.0	1.4270	0.0	0.	88.7	0.0	63
ACRYLIC ACID	72.06	1.0511	20.0	1.4224	13.5	0.	141.2	0.0	64
PROPIOLACTONE	72.06	1.1460	20.0	1.4131	-33.4	0.	155.0	0.0	65
ALLYL METHYL ETHER	72.11	0.7610	25.0	1.3786	0.0	0.	41.5	0.0	66
2-BUTANONE	72.11	0.8049	20.0	1.3788	-86.7	0.	79.6	18.51	67
2-BUTANONE	72.11	0.7997	25.0	1.3764	-86.7	0.	79.6	18.52	68
2-BUTENEOL-1 (CIS)	72.11	0.8540	20.0	1.4342	-89.4	760.	123.6	0.0	69
1,2-BUTYLENE OXIDE	72.11	0.8297	20.0	1.3840	-150.0	0.	63.2	0.0	70
BUTYRALDEHYDE	72.11	0.8016	20.0	1.3791	-96.4	0.	74.8	13.40	71
ISO-BUTYRALDEHYDE	72.11	0.7891	20.0	1.3727	-65.0	0.	64.1	0.0	72
ETHYLVINYL ETHER	72.11	0.7531	20.0	1.3754	-115.8	0.	35.7	0.0	73
METHALLYL ALCOHOL	72.11	0.8574	19.0	1.4255	0.0	0.	114.5	0.0	74
TETRAHYDROFURAN	72.11	0.8892	20.0	1.4050	-108.5	0.	66.0	7.58	75
TETRAHYDROFURAN.	72.11	0.8811	25.0	1.4050	-108.5	0.	66.0	7.58	76
1,2-EPOXY-2-ME PROPANE	72.12	0.8650	0.0	1.3712	0.0	760.	52.0	0.0	77
2,2-DIMETHYL PROPANE	72.15	0.6135	20.0	1.3476	-20.0	0.	9.5	0.0	78
2-METHYL BUTANE	72.15	0.6197	0.0	1.3537	-159.9	0.	27.9	1.84	79
PENTANE	72.15	0.6262	20.0	1.3579	-129.7	0.	36.1	0.0	80
NN-DIMETHYLFORMAMIDE	73.10	0.9440	25.0	1.4282	-60.4	760.	153.0	36.71	81
METHYL ISOTHIOCYANATE	73.12	1.0691	37.0	1.5258	36.0	758.	119.0	0.0	82
METHYL THIOCYANATE	73.12	1.0678	25.0	1.4669	-5.1	757.	132.9	0.0	83
SEC-BUTYL AMINE (D)	73.14	0.7240	20.0	1.3440	-104.5	0.	63.0	0.0	84
SEC-BUTYL AMINE (DL)	73.14	0.7271	17.0	1.3950	-72.0	772.	67.0	0.0	85

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
N-BUTYLAMINE	73.14	0.7346	25.0	1.3987	-49.1	0.	77.4	4.88	86
SEC-BUTYLAMINE	73.14	0.7246	20.0	1.3934	0.0	0.	62.5	0.0	87
DIETHYLAMINE	73.14	0.7070	20.0	1.3854	-49.8	0.	55.5	3.58	88
ISOBUTYLAMINE	73.14	0.7346	20.0	1.3972	-84.6	0.	67.7	4.43	89
TERT-BUTYLAMINE	73.14	0.6908	25.0	1.3761	-72.7	0.	44.4	0.0	90
DIOXOLANE	74.08	1.0600	20.0	1.3974	-95.0	765.	78.0	0.0	91
ETHYL FORMATE	74.08	0.9289	15.0	1.3625	-79.4	0.	54.1	7.16	92
HYDROXY ACETONE	74.08	1.0824	20.0	1.4295	-17.0	0.	145.5	0.0	93
3-HYDROXYPROPYLENEOXIDE	74.08	1.1110	22.0	1.4350	0.0	0.	166.5	0.0	94
METHYL ACETATE	74.08	0.9342	20.0	1.3614	-98.1	0.	56.3	6.68	95
PROPANOIC ACID	74.08	0.9880	25.0	1.3843	-20.7	0.	140.8	3.44	96
1-BUTANOL	74.12	0.8097	20.0	1.3993	-88.6	0.	117.7	17.51	97
1-BUTANOL	74.12	0.8060	25.0	1.3973	-88.6	0.	117.7	17.51	98
2-BUTANOL	74.12	0.8026	25.0	1.3950	-114.7	0.	99.6	16.56	99
DIETHYL ETHER	74.12	0.7138	20.0	1.3526	-116.2	760.	34.5	4.34	100
ETHYL ETHER	74.12	0.7076	25.0	1.3495	-116.3	0.	34.5	4.34	101
2-METHYL-1-PROPANOL	74.12	0.7978	25.0	1.3939	-108.0	0.	107.7	17.93	102
2-METHYL-2-PROPANOL	74.12	0.7808	25.0	1.3878	25.5	0.	82.2	1.77	103
METHYL PROPYL ETHER	74.12	0.7380	20.0	1.3579	0.0	760.	38.9	0.0	104
TERT BUTYL ALCOHOL	74.12	0.7887	20.0	1.3878	25.5	0.	82.2	1.77	105
1,2-PROPANEDIAMINE	74.13	0.8584	25.0	1.4492	0.0	760.	120.5	0.0	106
NITROETHANE	75.07	1.0446	25.0	1.3897	-89.5	0.	114.1	28.06	107
1-AMINO-2-PROPANOL	75.11	0.9730	18.0	1.4500	-1.0	750.	160.0	0.0	108
3-AMINO-2-PROPANOL	75.11	0.9824	26.0	1.4570	11.0	756.	187.0	0.0	109
2-METHOXYETHANOL	76.10	0.9602	25.0	1.4002	-85.1	0.	124.6	16.93	110
METHYLAL	76.10	0.8665	15.0	1.3563	-105.2	0.	42.3	2.65	111
1,2-PROPANEDIOL	76.10	1.0362	20.0	1.4329	-60.0	0.	187.6	32.00	112
1,3-PROPANEDIOL	76.10	1.0538	20.0	1.4396	-26.7	0.	214.4	35.00	113
CARBON DISULFIDE	76.14	1.2700	15.0	1.6319	-111.6	0.	46.2	2.64	114
1-PROPANE THIOL	76.17	0.8411	20.0	1.4380	-113.3	760.	67.5	0.0	115
2-PROPANE THIOL	76.17	0.8143	20.0	1.4255	-130.5	760.	52.6	0.0	116
3-CHLOROPROPENE	76.52	0.9442	15.0	1.4181	-134.5	0.	45.1	8.20	117
CIS-PROPENYL CHLORIDE	76.53	0.9347	20.0	1.4055	-134.8	760.	32.8	0.0	118
TRANS-PROPENYL CHLORIDE	76.53	0.9350	20.0	1.4054	-99.0	760.	37.4	0.0	119
BENZENE	78.12	0.8790	20.0	1.5011	5.5	0.	80.1	2.28	120
BENZENE	78.12	0.8737	25.0	1.4979	5.5	0.	80.1	2.28	121
DIMETHYLSULFOXIDE	78.13	1.0958	25.0	1.4773	18.5	0.	189.0	46.68	122
ETHANOL-1-THIOL-2	78.13	1.1143	0.0	1.4996	0.0	13.	55.0	0.0	123
ACETYL CHLORIDE	78.50	1.1050	20.0	1.3898	-112.0	0.	51.5	15.00	124
1-CHLOROPROPANE	78.54	0.8909	20.0	1.3879	-122.8	0.	46.6	7.70	125
2-CHLOROPROPANE	78.54	0.8617	20.0	1.3777	-117.2	0.	35.7	9.02	126
2-CHLOROPROPANE	78.54	0.8491	30.0	1.3711	-117.2	0.	35.7	9.82	127
PYRIDINE	79.10	0.9782	25.0	1.5075	-41.6	0.	115.3	12.40	128
PYRIDAZINE	80.09	1.1035	23.0	1.5231	-8.0	0.	208.0	0.0	129
PYRIMIDINE	80.09	0.0	0.0	0.0	22.0	0.	123.7	0.0	130
2-CHLOROETHANOL	80.52	1.2019	20.0	1.4438	-67.5	0.	128.6	25.80	131
1-METHYL PYRROLE	81.11	0.9145	15.0	1.4899	0.0	748.	114.5	0.0	132
1-METHYL IMIDAZOLE	82.10	1.6325	21.0	1.4924	-6.0	0.	198.0	0.0	133
CYCLOHEXENE	82.15	0.8061	25.0	1.4438	-103.5	0.	83.0	2.22	134
1,5-HEXADIENE	82.15	0.6923	0.0	1.4044	-141.0	0.	60.0	0.0	135
N-ME-ALANINE NITRILE	83.11	0.8992	20.0	1.4312	0.0	22.	82.0	0.0	136
VALERONITRILE	83.13	0.7950	25.0	1.3951	-96.2	0.	141.3	19.71	137
CYCLOPENTANONE	84.11	0.9509	0.0	1.9366	-51.3	0.	130.7	0.0	138
THIOPHENE	84.14	1.0649	20.0	1.5289	-38.2	0.	84.2	2.71	139
CYCLOHEXANE	84.16	0.7786	20.0	1.4262	6.6	0.	80.7	2.02	140
CYCLOHEXANE	84.16	0.7739	25.0	1.4235	6.6	0.	80.7	2.02	141
1-HEXENE	84.16	0.6685	25.0	1.3850	-139.8	0.	63.5	2.05	142
METHYL CYCLOPENTANE	84.16	0.7489	20.0	1.4096	-142.4	0.	72.1	1.98	143
DICHLOROMETHANE	84.93	1.3148	25.0	1.4211	-95.1	0.	39.8	8.93	144
ACETONE CYANOHYDRIN	85.11	0.9320	19.0	1.3996	-190.0	0.	82.0	0.0	145
2-PYRROLIDINONE	85.11	1.1070	25.0	1.4860	25.0	0.	245.0	0.0	146
PIPERIDINE	85.15	0.8616	20.0	1.4525	-10.5	0.	106.4	5.80	147
ALLYL FORMATE	86.09	0.9498	18.0	1.3980	0.0	0.	83.0	0.0	148
CIS-2-BUTENOIC ACID	86.09	1.0267	20.0	1.4483	15.5	760.	169.3	0.0	149
BUTYROLACTONE	86.09	1.1254	25.0	1.4348	-43.5	760.	204.0	39.00	150
METHACRYLIC ACID	86.09	1.0153	20.0	1.4314	15.0	760.	160.5	0.0	151
METHYL ACRYLATE	86.09	0.9547	18.0	1.4117	-75.0	0.	80.2	0.0	152
VINYL ACETATE	86.09	0.9312	20.0	1.3959	-92.8	0.	72.5	0.0	153
ALLYL ETHYL ETHER	86.13	0.7597	25.0	1.3861	64.0	0.	0.0	0.0	154
2-PENTANONE	86.13	0.8124	15.0	1.3895	-77.8	0.	102.0	0.0	155
3-PENTANONE	86.13	0.8095	25.0	1.3900	-39.0	0.	102.0	17.00	156
1-PENTENE-3-OL	86.13	0.8395	22.0	1.4183	0.0	0.	115.0	0.0	157
TETRAHYDROPYRAN	86.13	0.8772	25.0	1.4195	-45.0	0.	88.0	5.61	158
TRI-ME ACETALDEHYDE	86.13	0.7927	17.0	1.3791	6.0	0.	75.0	0.0	159
VALERALDEHYDE	86.13	0.8095	20.0	1.3944	-91.5	0.	102.5	10.00	160
2,2-DIMETHYL BUTANE	86.17	0.6492	0.0	1.3687	-99.9	0.	49.7	0.0	161
2,3-DIMETHYL BUTANE	86.17	0.6616	0.0	1.3749	-128.5	0.	57.9	0.0	162
HEXANE	86.17	0.6548	25.0	1.3723	-95.3	0.	68.7	1.89	163
HEXANE	86.17	0.6594	0.0	1.3749	-95.3	0.	68.7	1.89	164
2-METHYL PENTANE	86.17	0.6532	0.0	1.3714	-153.7	0.	60.3	0.0	165
3-METHYL PENTANE	86.17	0.6643	0.0	1.3765	0.0	0.	63.3	0.0	166
N,N-DIMEACETAMIDE	87.12	0.9366	25.0	1.4356	-20.0	0.	166.1	37.78	167
N-ME PROPIONAMIDE	87.12	0.9305	25.0	1.4345	-30.9	0.	148.0	172.20	168
MORPHOLINE	87.12	1.0050	25.0	1.4573	-3.1	0.	128.9	7.42	169
ETHYL ISOTHIOCYANATE	87.14	0.9990	20.0	1.5130	-5.9	760.	131.5	0.0	170

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
1-AMINOPENTANE	87.17	0.7547	20.0	1.4118	-55.0	760.	104.4	0.0	171
ETHYLENE CARBONATE	88.06	1.3208	25.0	1.4250	36.4	0.	238.0	89.60	172
PYRROLINE	88.06	1.2272	0.0	1.4138	13.6	0.	115.0	0.0	173
PYRUVIC ACID	88.06	1.2272	20.0	1.4280	13.6	760.	165.0	0.0	174
ALDOL	88.10	1.1030	20.0	1.4497	0.0	12.	79.0	0.0	175
CIS-2-BUTENE-14-DIOL	88.11	1.0740	20.0	1.4793	11.0	0.	235.0	0.0	176
TRN-2-BUTENE-14-DIOL	88.11	1.0685	20.0	1.4779	27.3	0.	132.0	0.0	177
BUTYRIC ACID	88.11	0.9532	25.0	1.3958	-5.2	0.	163.3	2.97	178
1,3-DIOXANE	88.11	1.3042	20.0	1.4165	-42.0	755.	105.0	0.0	179
P-DIOXANE	88.11	1.0280	25.0	1.4203	11.8	0.	101.3	2.21	180
ETHYL ACETATE	88.11	0.9006	20.0	1.3724	-83.9	0.	77.1	6.02	181
ETHYL ACETATE	88.11	0.8946	25.0	1.3698	-83.9	0.	77.1	6.02	182
ISOBUTYRIC ACID	88.11	0.9682	20.0	1.3930	-46.1	0.	154.7	2.73	183
METHYLPROPIONATE	88.11	0.9151	20.0	1.3779	-87.5	0.	78.7	5.50	184
PROPYL FORMATE	88.11	0.9111	15.0	1.3790	-92.9	0.	80.8	7.72	185
VALERONITRILE	88.13	0.8034	15.0	1.3991	-96.2	0.	141.3	19.71	186
ETHYL-N-PROPYL ETHER	88.15	0.7330	0.0	1.3695	-79.0	0.	63.6	0.0	187
2-METHYL-1-BUTANOL	88.15	0.8152	25.0	1.4087	-70.0	760.	128.7	14.70	188
3-METHYL-1-BUTANOL	88.15	0.8071	25.0	1.4052	-117.2	60.	130.5	14.70	189
2-METHYL-2-BUTANOL	88.15	0.8050	25.0	1.4024	-8.8	0.	102.0	5.82	190
3-METHYL-2-BUTANOL	88.15	0.8138	25.0	1.4075	0.0	0.	111.5	0.0	191
METHYL-N-BUTYL ETHER	88.15	0.7443	0.0	1.3736	-115.5	0.	71.0	0.0	192
1-PENTANOL	88.15	0.8115	25.0	1.4079	-78.2	0.	137.8	13.90	193
2-PENTANOL	88.15	0.8054	25.0	1.4044	0.0	0.	119.0	13.82	194
3-PENTANOL	88.15	0.8160	25.0	1.4079	0.0	0.	115.3	13.02	195
TETRAHYDROTHIOPHENE	88.17	0.9938	25.0	1.5257	-96.2	0.	120.9	0.0	196
1-NITROPROPANE	89.10	1.9961	25.0	1.3996	-104.0	0.	131.2	23.24	197
2-NITROPROPANE	89.10	0.9829	25.0	1.3924	-91.3	0.	120.3	25.52	198
2-AMINO-1-BUTANOL	89.14	0.9162	20.0	1.4489	-2.0	0.	178.0	0.0	199
3-AMINO-2-BUTANOL	89.14	0.9299	25.0	1.4502	19.0	745.	159.5	0.0	200
DIMETHYL ETHANOLAMINE	89.14	0.8866	20.0	1.4300	0.0	760.	134.0	0.0	201
2-ETHYLAMINOETHANOL	89.14	0.9140	20.0	1.4440	-9.0	760.	169.5	0.0	202
3-CHLOROPROPIONITRILE	89.53	1.1375	0.0	1.4380	0.0	0.	58.0	0.0	203
DIMETHYL CARBONATE	90.08	1.0694	20.0	1.3687	3.0	0.	90.5	0.0	204
LACTIC ACID DL	90.08	1.2060	25.0	1.4392	18.0	12.	119.0	0.0	205
METHOXYACETIC ACID	90.08	1.1768	20.0	1.4168	0.0	760.	213.0	0.0	206
METHYL GLYCOLATE	90.08	1.1677	18.0	0.0	0.0	760.	151.1	0.0	207
1,2-BUTANEDIOL	90.12	1.0059	20.0	1.4375	0.0	0.	193.0	0.0	208
1,3-BUTANEDIOL	90.12	1.0053	20.0	1.4410	77.0	0.	207.5	0.0	209
1,4-BUTANEDIOL	90.12	1.0171	20.0	1.4460	20.1	0.	235.0	0.0	210
2,3-BUTANEDIOL	90.12	0.9872	20.0	1.4306	34.0	760.	181.0	0.0	211
1,2-DIMETHOXYETHANE	90.12	0.8629	20.0	1.3796	-58.0	760.	83.5	0.0	212
2-ETHOXYETHANOL	90.12	0.9252	25.0	1.4057	-90.0	0.	135.6	29.60	213
1-METHOXYPROPANOL-2	90.12	0.9620	20.0	1.4070	0.0	0.	118.3	0.0	214
1-METHOXYPROPANOL-2	90.12	0.9620	20.0	1.4070	0.0	0.	118.3	0.0	215
1-BUTANETHIOL	90.19	0.8416	20.0	1.4429	-115.7	0.	98.4	5.07	216
ETHYL SULFIDE	90.19	0.8312	25.0	1.4402	-103.9	0.	92.1	5.72	217
CIS-1-CL-1-BUTENE	90.55	0.9153	15.0	1.4194	0.0	760.	63.5	0.0	218
TRANS-1-CL-1-BUTENE	90.55	0.9205	15.0	1.4225	0.0	760.	68.0	0.0	219
2-CHLORO-1-BUTENE	90.55	0.9107	15.0	1.4115	0.0	760.	58.7	0.0	220
3-CHLORO-1-BUTENE	90.55	0.8978	20.0	1.4149	0.0	766.	64.5	0.0	221
4-CHLORO-1-BUTENE	90.55	0.9211	20.0	1.4233	0.0	773.	75.0	0.0	222
CIS-1-CL-2-BUTENE	90.55	0.9426	20.0	1.4390	0.0	758.	84.1	0.0	223
TRANS-1-CL-2-BUTENE	90.55	0.9295	20.0	1.4350	0.0	752.	84.8	0.0	224
CIS-2-CL-2-BUTENE	90.55	0.9239	20.0	1.4240	-117.3	760.	70.6	0.0	225
TRANS-2-CL-2-BUTENE	90.55	0.9138	20.0	1.4190	-105.8	760.	628.0	0.0	226
1-CL-2-ME-PROPENE-1	90.55	0.9250	16.0	1.4221	0.0	775.	68.0	0.0	227
3-CL-2-ME-PROPENE-1	90.55	0.9250	20.0	1.4270	0.0	0.	72.0	0.0	228
2-NITROETHANOL-1	91.07	1.2700	15.0	1.4438	-80.0	765.	194.0	0.0	229
1,2,3-PROPANETRIOL	92.10	1.2613	20.0	1.4746	18.2	0.	290.0	42.50	230
TOLUENE	92.14	0.8669	20.0	1.4969	-94.9	0.	110.6	2.38	231
TOLUENE	92.14	0.8623	25.0	1.4941	-94.9	0.	110.6	2.38	232
CHLOROACETONE	92.53	1.1500	20.0	0.0	-44.5	0.	119.0	0.0	233
EPICHLOROHYDRIN	92.53	1.1807	20.0	1.4380	-57.2	0.	116.1	22.60	234
TERT-BUTTL CHLORIDE	92.57	0.8420	20.0	1.3857	-25.4	760.	52.0	0.0	235
1-CHLOROBUTANE	92.57	0.8862	20.0	1.4021	-123.1	0.	78.4	7.39	236
2-CHLOROBUTANE	92.57	0.8732	20.0	1.3971	-140.5	0.	68.3	7.09	237
1-CL-2-METHYLPROPANE	92.57	0.8773	20.0	1.3980	-130.3	0.	68.8	6.49	238
2-CL-2-METHYLPROPANE	92.57	0.8420	20.0	1.3857	-25.4	0.	50.7	9.96	239
ANILINE	93.13	1.0217	20.0	1.5863	-6.0	0.	184.4	6.89	240
2-METHYLPYRIDINE	93.13	0.9497	15.0	1.5029	0.0	0.	128.8	9.80	241
3-METHYLPYRIDINE	93.13	0.9613	15.0	1.5043	0.0	0.	143.5	9.80	242
GLUTARONITRILE	94.12	0.9911	15.0	1.4295	-29.0	0.	286.0	0.0	243
PHENOL	94.12	1.0576	41.0	1.5428	40.9	0.	181.8	9.78	244
1,2-DIHYDROTOLUENE	94.16	0.8354	0.0	1.4763	0.0	0.	110.0	0.0	245
1-CHLORO-2-PROPANOL	94.54	1.1100	20.0	1.4392	0.0	762.	126.5	0.0	246
3-CHLORO-1-PROPANOL	94.54	1.1309	0.0	1.4450	0.0	0.	161.5	0.0	247
PYRROLE-2-CARBOXALDEHYDE	95.10	0.0	16.0	1.5939	46.5	0.	218.0	0.0	248
2,5-DIME-PYRROLE	95.14	0.9353	20.0	1.5025	0.0	765.	171.0	0.0	249
1-ETHYL-PYRROLE	95.15	0.9009	20.0	1.4841	0.0	0.	164.0	0.0	250
1,4-PYRONE	96.08	1.1900	0.0	1.5238	32.5	742.	216.0	0.0	251
2-FURALDEHYDE	96.09	1.1598	20.0	1.5261	-36.5	0.	161.8	38.00	252
FLUOROBENZENE	96.10	1.0309	15.0	1.4684	-42.2	0.	84.7	0.0	253
2,5-DIMETHYL FURAN	96.14	0.8883	20.0	1.4363	-62.8	760.	93.5	0.0	254
2,4-HEPTADIENE	96.17	0.7384	0.0	1.4578	0.0	0.	108.0	0.0	255

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
1-HEPTYNE	96.17	0.7338	20.0	1.4084	-81.0	760.	100.0	0.0	256
1,1-DICHLOROETHYLENE	96.94	1.2132	20.0	1.4247	-122.6	0.	31.6	4.60	257
CIS-1,2-DICLETHYLENE	96.94	1.2837	20.0	1.4490	-80.0	0.	60.6	9.20	258
TRANS1,2DICLETHYLENE	96.94	1.2547	20.0	1.4462	-49.8	0.	47.7	2.14	259
CAPRONITRILE	97.16	0.8052	20.0	1.4069	-80.3	0.	163.6	17.26	260
4-MEVALERONITRILE	97.16	0.7993	25.0	1.4040	-51.1	0.	154.0	15.50	261
FURFURYL ALCOHOL	98.10	1.1238	30.0	1.4801	-29.0	0.	170.0	0.0	262
2-METHOXY FURAN	98.10	1.0646	25.0	1.4468	0.0	0.	110.5	0.0	263
PROPARGYL ACETATE	98.10	0.9982	20.0	1.4187	0.0	0.	121.5	0.0	264
PROPARGYL ACETATE	98.10	0.9982	20.0	1.4187	0.0	0.	121.5	0.0	265
3,4-DIMETHYL FURAZAN	98.11	1.0528	14.0	1.4237	-7.0	744.	156.0	0.0	266
ALLYL ACETONE	98.14	0.8470	0.0	1.4917	0.0	0.	128.0	0.0	267
ALLYL ETHER	98.15	0.8006	25.0	1.4141	0.0	0.	0.0	0.0	268
CYCLOHEXANONE	98.15	0.9510	25.0	1.4520	-32.1	0.	155.6	18.30	269
MESITYL OXIDE	98.15	0.8653	20.0	1.4440	-52.9	760.	129.8	0.0	270
2-METHYLTHIOPHENE	98.17	1.0193	20.0	1.5203	-63.4	760.	112.6	0.0	271
3-METHYLTHIOPHENE	98.17	1.0218	20.0	1.5204	-69.0	760.	115.4	0.0	272
METHYL CYCLOHEXANE	98.18	0.7694	0.0	1.4231	-126.6	0.	98.2	0.0	273
1-HEPTENE	98.19	0.6970	20.0	1.3998	-118.9	760.	93.6	2.07	274
1,1-DICHLOROETHANE	98.96	1.1680	25.0	1.4138	-97.0	0.	57.3	10.10	275
1,2-DICHLOROETHANE	98.96	1.2458	25.0	1.4421	-35.7	0.	83.5	10.36	276
METHYLCYANOACETATE	99.09	1.1225	25.0	1.4166	-13.1	0.	205.1	29.30	277
1-ME-2-PYRROLIDINONE	99.13	1.0279	25.0	1.4680	-24.4	760.	202.0	32.00	278
1-ME-2-PYROLIDONE	99.13	1.0279	25.0	1.4680	-24.4	10.	79.0	32.00	279
ALLYLISOTHIOCYANATE	99.16	1.0126	20.0	1.5306	-80.0	760.	152.0	17.20	280
N-METHYL PIPERIDINE	99.17	0.8159	0.0	1.4355	0.0	0.	107.0	0.0	281
CYCLOHEXYLAMINE	99.18	0.8671	20.0	1.4592	-17.7	0.	134.8	4.73	282
2,4-DIME-PYRROLIDINE	99.18	0.8297	20.0	1.4325	0.0	753.	116.0	0.0	283
ALLYL ACETATE	100.12	0.9280	20.0	1.4040	0.0	0.	104.0	0.0	284
ETHYL ACRYLATE	100.12	0.9234	20.0	1.4068	-71.2	0.	99.5	0.0	285
METHYLMETHACRYLATE	100.12	0.9433	20.0	1.4146	-48.2	0.	100.3	2.90	286
2,3 PENTANEDIONE	100.12	0.9565	19.0	1.4014	0.0	0.	108.0	0.0	287
2,4 PENTANEDIONE	100.12	0.9721	25.0	1.4541	-23.0	734.	139.0	0.0	288
GAMMA-VALEROLACTONE	100.12	1.0520	25.0	1.4320	-37.0	0.	206.0	0.0	289
CYCLOBUT-CARBOXYLIC ACID	100.13	1.0599	20.0	1.4400	-2.0	754.	190.0	0.0	290
BUTYLVINYL ETHER	100.16	0.7727	25.0	1.3997	-92.0	0.	93.8	0.0	291
CYCLOHEXANOL	100.16	0.9684	25.0	1.4648	25.1	0.	161.1	15.00	292
2-HEXANONE	100.16	0.8116	0.0	1.4015	-57.0	0.	126.0	0.0	293
METHYL-T-BUTYL KETONE	100.16	0.8016	0.0	1.3952	-52.5	0.	106.0	0.0	294
3-ME-2-PENTANONE	100.16	0.8181	14.0	1.4002	0.0	0.	118.0	0.0	295
4-METHYL-2-PENTANONE	100.16	0.8008	20.0	1.3957	-84.0	0.	116.5	13.11	296
HEPTANE	100.19	0.6836	20.0	1.3876	-90.6	0.	98.4	0.0	297
HEPTANE	100.19	0.6795	25.0	1.3851	-90.6	0.	98.4	0.0	298
2-METHYL HEXANE	100.19	0.6744	25.0	1.3848	-118.3	0.	90.1	0.0	299
3-METHYL HEXANE	100.19	0.6829	25.0	1.3886	-119.4	0.	91.9	0.0	300
2,3-DIMETHYL PENTANE	100.21	0.6909	25.0	1.3920	0.0	0.	89.8	0.0	301
2,4-DIMETHYL PENTANE	100.21	0.6683	25.0	1.3814	-119.2	0.	80.5	0.0	302
3,3-DIMETHYL PENTANE	100.21	0.6933	0.0	1.3909	-135.0	0.	86.1	0.0	303
2,2,3-TRIMETHYLBUTANE	100.21	0.6901	20.0	1.3894	-25.0	0.	80.9	0.0	304
N-METHYLMORPHOLINE	101.15	0.9051	20.0	1.4332	0.0	750.	115.0	0.0	305
DIISOPROPYLAMINE	101.19	0.7153	20.0	1.3924	-96.3	0.	83.9	0.0	306
DIPROPYLAMINE	101.19	0.7375	20.0	1.4043	-63.0	0.	109.2	3.07	307
TRIETHYLAMINE	101.19	0.7230	25.0	1.3980	-114.7	0.	89.5	2.42	308
ACETIC ANHYDRIDE	102.09	1.0871	15.0	1.3930	-73.1	0.	140.0	20.70	309
4-METHYL DIOXOLANE	102.09	1.2069	20.0	1.4189	-46.8	760.	242.0	0.0	310
BUTYL FORMATE	102.13	0.8917	20.0	1.3890	-90.0	0.	106.6	2.43	311
ETHYL PROPIONATE	102.13	0.8957	15.0	1.3864	-73.9	0.	99.1	5.65	312
ETHYL PROPIONATE	102.13	0.8899	20.0	1.3839	-73.9	0.	99.1	5.65	313
ISOBUTYL FORMATE	102.13	0.8853	20.0	1.3855	-94.5	0.	98.4	6.41	314
ISOPROPYL ACETATE	102.13	0.8717	20.0	1.3773	-73.4	0.	88.2	0.0	315
ISOVALERIC ACID	102.13	0.9308	15.0	1.4064	-29.3	0.	176.5	2.64	316
METHYL-N-BUTYRATE	102.13	0.8984	20.0	1.3870	-95.0	0.	102.6	5.60	317
4-ME-1,3-DIOXANE	102.13	0.9953	20.0	1.4168	0.0	0.	114.0	0.0	318
PROPYL ACETATE	102.13	0.8938	15.0	1.3866	-92.5	0.	101.5	6.00	319
TETRA H FURFURYL ALC	102.13	1.0420	25.0	1.4599	0.0	0.	178.0	13.61	320
VALERIC ACID	102.13	0.9345	35.0	1.4060	33.7	0.	185.5	2.66	321
BUTYL ETHYL ETHER	102.18	0.7448	25.0	1.3793	-103.0	0.	92.2	0.0	322
2-ETHYL-1-BUTANOL	102.18	0.8295	25.0	1.4205	-114.4	0.	146.5	6.09	323
1-HEXANOL	102.18	0.8159	25.0	1.4161	-44.6	0.	157.0	13.30	324
ISOPROPYL ETHER	102.18	0.7182	25.0	1.3655	-85.5	0.	68.3	3.88	325
2-METHYL-2-PENTANOL	102.18	0.8350	16.0	1.4125	108.0	0.	121.5	0.0	326
3-METHYL-2-PENTANOL	102.18	0.8235	25.0	1.4179	0.0	0.	134.3	0.0	327
4-METHYL-2-PENTANOL	102.18	0.8075	20.0	1.4100	-90.0	760.	133.5	0.0	328
3-METHYL-3-PENTANOL	102.18	0.8237	20.0	1.4180	-38.0	0.	121.0	0.0	329
PROPYL ETHER	102.18	0.7419	25.0	1.3780	-123.2	0.	89.6	3.39	330
BENZONITRILE	103.12	1.0006	25.0	1.5259	-12.8	0.	191.1	25.20	331
METHYL URETHANE	103.12	1.0350	15.0	1.4200	0.0	760.	170.0	0.0	332
1-NITROBUTANE	103.12	0.9880	0.0	1.4103	0.0	0.	153.0	0.0	333
DIETHYLENETRIAMINE	103.17	0.9586	20.0	1.4810	-39.0	760.	207.0	0.0	334
METHYL LACTATE	104.12	1.0857	26.0	1.4131	-66.0	760.	144.8	0.0	335
STYRENE	104.14	0.9012	25.0	1.5440	-30.6	0.	145.2	2.43	336
DIETHOXYMETHANE	104.15	0.8319	20.0	1.3748	-665.0	0.	88.0	0.0	337
N-PROPYL NITRATE	105.09	1.0580	0.0	1.3976	0.0	0.	110.5	0.0	338
DIETHANOLAMINE	105.14	1.0899	30.0	1.4747	28.0	0.	268.4	2.81	339
BENZALDEHYDE	106.12	1.0447	20.0	1.5455	-26.0	0.	178.9	17.80	340

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
DIETHYLENE GLYCOL	106.12	1.1164	20.0	1.4475	-10.5	0.	244.8	31.69	341
METHOXYMETHOXYETHANOL	106.12	1.0385	25.0	1.4100	-70.0	0.	167.5	0.0	342
ETHYL BENZENE	106.17	0.8626	25.0	1.4932	-94.9	0.	136.2	2.40	343
O-XYLENE	106.17	0.8759	25.0	1.5029	-25.2	0.	144.4	2.57	344
M-XYLENE	106.17	0.8599	25.0	1.4946	-47.8	0.	139.1	2.37	345
P-XYLENE	106.17	0.8611	20.0	1.4958	13.3	0.	138.3	2.27	346
P-XYLENE	106.17	0.8567	25.0	1.4933	13.3	0.	138.3	2.27	347
BENZYLAMINE	107.15	0.9813	20.0	1.5402	10.0	770.	185.0	0.0	348
2,4-DIMETHYL PYRIDINE	107.15	0.9271	25.0	1.4984	0.0	0.	159.2	0.0	349
2,5-DIME PYRIDINE	107.15	0.9261	25.0	1.4982	-15.0	0.	156.8	0.0	350
2,6-DIME PYRIDINE	107.15	0.9200	25.0	1.4953	-5.0	0.	143.0	0.0	351
3,5-DIME PYRIDINE	107.15	0.9385	25.0	1.5032	0.0	0.	171.6	0.0	352
3,4-DIME PYRIDINE	107.15	0.9537	25.0	1.5099	-12.0	759.	178.8	0.0	353
METHYL ANILINE	107.15	0.9891	0.0	1.5702	-57.0	0.	196.3	5.97	354
O-TOLUIDINE	107.16	0.9984	20.0	1.5725	-16.1	0.	200.4	6.34	355
M-TOLUIDINE	107.16	0.9930	15.0	1.5704	-30.4	0.	203.4	5.95	356
P-TOLUIDINE	107.16	0.9659	45.0	1.5540	43.8	0.	200.6	4.98	357
ADIPONITRILE	108.14	0.9510	19.0	1.4597	2.0	0.	180.0	0.0	358
ANISOLE	108.14	0.9893	25.0	1.5143	-37.5	0.	153.8	4.33	359
BENZYL ALCOHOL	108.14	1.0454	20.0	1.5403	-15.3	0.	205.4	13.10	360
BENZYL ALCOHOL	108.14	1.0413	25.0	1.5384	-15.3	0.	205.4	13.10	361
O-CRESOL	108.14	1.1350	25.0	1.5442	30.9	0.	191.0	11.50	362
M-CRESOL	108.14	1.0302	25.0	1.5396	12.2	0.	202.2	11.80	363
P-CRESOL	108.14	1.0178	41.0	1.5311	34.7	0.	201.9	9.91	364
1,3-PROPANEDITHIOL	108.23	1.0783	20.0	1.5403	-79.0	0.	172.9	0.0	365
ETHYL CHLOROFORMATE	108.53	1.3577	20.0	1.3955	-80.6	760.	95.0	0.0	366
METHYL CHLOROACETATE	108.53	1.2337	20.0	1.4218	-32.1	760.	129.8	0.0	367
BROMOETHANE	108.97	1.4708	15.0	1.4276	-118.6	0.	38.4	9.39	368
O-FLUOROTOLUENE	110.13	1.0027	15.0	1.4716	-62.0	0.	114.4	4.22	369
M-FLUOROTOLUENE	110.13	0.9974	20.0	1.4691	-87.7	760.	116.5	0.0	370
P-FLUOROTOLUENE	110.13	0.9975	20.0	1.4688	-56.8	760.	116.6	5.86	371
BENZENETHIOL	110.18	1.0727	25.0	1.5872	-14.9	0.	169.1	4.38	372
THIO-PHENOL	110.18	1.0728	25.0	1.5879	70.5	0.	169.5	0.0	373
2,3-DICHLOROPROPENE	110.98	1.2040	25.0	1.4600	0.0	0.	94.0	0.0	374
ACETAZINE	112.17	0.8422	20.0	1.4535	-125.0	0.	133.0	0.0	375
2-METHYLCYCLOHEXANONE	112.17	0.9240	20.0	1.4493	0.0	757.	165.0	0.0	376
THIOXENE	112.19	0.9956	0.0	1.5130	0.0	0.	137.8	0.0	377
P-DIMETHYLCYCLOHEXANE	112.21	0.7827	0.0	1.4253	-87.0	0.	124.6	0.0	378
ETHYL CYCLOHEXANE	112.21	0.7839	25.0	1.4330	-111.3	0.	131.8	0.0	379
OCTENE-1	112.21	0.7149	20.0	1.4087	-101.7	0.	121.3	0.0	380
DI-ISO-BUTYLENE	112.22	0.7122	25.0	1.4090	0.0	0.	101.0	0.0	381
CHLOROBENZENE	112.56	1.1117	15.0	1.5275	-45.6	0.	131.7	5.62	382
1,2-DICHLOROPROPANE	112.99	1.1560	20.0	1.4394	-100.4	760.	96.4	0.0	383
1,3-DICHLOROPROPANE	112.99	1.1878	20.0	1.4487	-99.5	760.	120.4	0.0	384
2,2-DICHLOROPROPANE	112.99	1.1120	20.0	1.4148	-33.8	760.	69.3	0.0	385
1,1-DICHLOROPROPANE	112.99	1.1321	20.0	1.4289	0.0	760.	88.1	0.0	386
ETHYL CYANOACETATE	113.12	1.0614	20.0	1.4155	-22.5	0.	206.0	26.70	387
CHLOROACETYL CHLORIDE	113.94	1.4202	20.0	1.4541	0.0	760.	107.0	0.0	388
TRIFLUOROACETIC ACID	114.02	1.4890	20.0	1.2850	-15.3	0.	71.8	8.55	389
ALLYL PROPIONATE	114.14	0.9037	25.0	1.4110	0.0	0.	124.0	0.0	390
2,5-HEXANEDIONE	114.14	0.7370	0.0	1.4232	-5.5	754.	194.0	0.0	391
2,4-DIME-3-PENTANONE	114.18	0.8062	20.0	1.4001	0.0	0.	124.0	0.0	392
2-HEPTANONE	114.18	0.8111	20.0	1.4116	-35.0	0.	151.0	0.0	393
3-HEPTANONE	114.18	0.8183	20.0	0.0	39.0	0.	50.0	0.0	394
4-HEPTANONE	114.18	0.8174	20.0	1.4073	-33.0	0.	144.0	0.0	395
CYCLOHEXYLMETHYL ETHER	114.19	0.8790	20.0	1.4355	-74.4	760.	133.0	0.0	396
1-METHYLCYCLOHEXANOL	114.19	0.9251	24.6	1.4587	26.0	0.	157.0	0.0	397
2-METHYLCYCLOHEXANOL	114.19	0.9254	20.0	1.4610	0.0	0.	167.6	13.30	398
CIS-2-ME CYCLOHEXANOL	114.19	0.9360	20.0	1.4640	7.0	0.	165.0	0.0	399
TRN-2-ME CYCLOHEXANOL	114.19	0.9247	20.0	1.4616	-4.0	0.	166.5	0.0	400
3-METHYLCYCLOHEXANOL	114.19	0.9168	20.0	1.4576	0.0	0.	172.0	12.30	401
CIS-3-ME CYCLOHEXANOL	114.19	0.9155	20.0	1.4572	-5.5	0.	168.0	16.47	402
TRN-3-ME CYCLOHEXANOL	114.19	0.9214	20.0	1.4580	-0.5	0.	84.0	8.05	403
4-METHYLCYCLOHEXANOL	114.19	0.9122	20.0	1.4565	0.0	763.	172.0	13.30	404
5-METHYL-3-HEXANONE	114.19	0.8150	17.0	1.3970	0.0	735.	134.0	0.0	405
ISO OCTANE	114.22	0.6918	0.0	1.3915	-107.4	0.	99.2	0.0	406
OCTANE	114.22	0.7025	20.0	1.3974	-56.8	0.	125.6	1.95	407
OCTANE	114.22	0.6985	25.0	1.3951	-56.8	0.	125.6	1.95	408
2,2,4-TRIME PENTANE	114.22	0.7078	0.0	1.3914	-107.4	0.	98.2	1.94	409
2,2,3-TRIME PENTANE	114.22	0.7121	25.0	1.4006	-112.3	0.	109.8	1.96	410
ACETONYLUREA	116.12	0.8018	4.0	0.0	-41.0	0.	82.0	0.0	411
METHYLACETOACETATE	116.12	1.0747	20.0	1.4186	-80.0	0.	171.7	0.0	412
1-UREIDO-2-PROPANONE	116.12	0.8018	4.0	0.0	-41.0	0.	82.0	0.0	413
BETA-ACETOPROPIONIC ACID	116.13	1.1335	20.0	1.4396	37.2	0.	245.8	0.0	414
INDENE	116.15	0.9915	0.0	1.5642	-2.0	0.	182.2	0.0	415
4-ME-2-PENTANONE-4-OL	116.15	0.9385	0.0	1.4235	-44.0	0.	166.0	0.0	416
AMYL FORMATE	116.16	0.8926	15.0	1.3992	-73.5	0.	132.1	0.0	417
BUTYL ACETATE	116.16	0.8713	30.0	1.3827	-73.5	0.	126.1	5.01	418
SEC BUTYL ACETATE	116.16	0.8720	20.0	1.3894	0.0	0.	112.3	0.0	419
CAPROIC ACID	116.16	0.9230	25.0	1.4148	-3.9	0.	205.7	2.63	420
DIACETONE ALCOHOL	116.16	0.9342	25.0	1.4213	-44.0	12.	168.1	18.20	421
ETHYL BUTYRATE	116.16	0.8791	20.0	1.3928	-98.0	0.	121.6	5.10	422
ETHYL ISOBUTYRATE	116.16	0.8693	20.0	1.3903	-88.2	0.	111.0	0.0	423
ISOAMYL FORMATE	116.16	0.8820	20.0	1.3476	0.0	0.	124.2	0.0	424
ISOBUTYL ACETATE	116.16	0.8695	25.0	1.3880	-98.8	0.	118.0	5.29	425

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
N-PROPYL PROPIONATE	116.16	0.8330	0.0	1.6015	-76.0	0.	122.5	0.0	426
1122TETRAME UREA	116.16	0.9654	25.0	1.4493	-1.2	0.	175.2	23.06	427
2-HEPTANOL	116.21	0.8171	20.0	1.4210	0.0	0.	159.7	9.21	428
PHENYLACETONITRILE	117.14	1.0155	0.0	1.5233	-23.8	0.	233.5	0.0	429
TOLUIC NITRILE	117.15	1.0125	25.0	1.5209	-23.8	0.	233.5	18.70	430
1-AMINO-2-ME-2-PENTANOL	117.19	0.9081	20.0	1.4510	0.0	15.	83.0	0.0	431
2-BUTYLAMINO ETHANOL	117.19	0.8907	20.0	1.4437	-3.5	760.	199.5	0.0	432
DIMETHYL OXALATE	118.09	1.1716	60.0	1.3790	5.4	760.	164.5	0.0	433
GLYCOL DIFORMATE	118.09	1.1930	1.0	1.3580	-10.0	0.	174.0	0.0	434
ACETAL	118.12	0.8213	25.0	1.3682	0.0	0.	103.6	3.80	435
DIETHYL CARBONATE	118.13	0.9693	25.0	1.3829	-43.0	0.	126.8	2.82	436
ETHYL LACTATE	118.13	1.0328	20.0	1.4124	-26.0	0.	154.5	13.10	437
ETHYL LACTATE	118.13	1.0272	25.0	1.4127	-26.0	36.	69.5	13.10	438
2-MEOXYETHYLACETATE	118.13	1.0049	20.0	1.4022	-65.1	0.	144.5	8.25	439
DIETHOXYETHANE	118.17	0.8341	0.0	1.3819	0.0	0.	102.2	0.0	440
ALPHA-METHYL STYRENE	118.17	0.9140	0.0	0.0	-20.0	765.	165.0	0.0	441
2-BUTOXYETHANOL	118.18	0.9008	20.0	1.4198	0.0	760.	170.2	9.30	442
2-METHYL-2,4-PENTANEDIOL	118.18	0.9254	17.0	1.4250	-40.0	760.	197.0	0.0	443
CHLOROCYCLOHEXANE	118.61	1.0000	20.0	1.4626	-43.9	0.	143.0	0.0	444
PHENYL CARBONIMIDE	119.12	1.0960	0.0	1.5350	0.0	0.	165.0	0.0	445
TRIAZOBENZENE	119.13	1.0880	20.0	1.5589	-27.0	11.	70.0	0.0	446
CHLOROFORM	119.38	1.4799	25.0	1.4429	-63.5	0.	61.1	4.81	447
ACETOPHENONE	120.15	1.0281	20.0	1.5342	19.6	0.	202.0	17.39	448
GLYCEROL DIMETHYL ETHER	120.15	1.0085	0.0	1.4192	0.0	0.	169.0	0.0	449
2-(2-MEOETO)ETHANOL 328	120.15	1.0167	25.0	1.4245	-70.0	0.	194.1	0.0	450
PHENYL ETHYLENE OXIDE	120.15	1.0469	25.0	1.5350	-35.6	0.	191.5	0.0	451
STYRENE OXIDE	120.15	1.0469	25.0	1.5350	-35.6	0.	191.5	0.0	452
SULFOLANE	120.17	1.2614	30.0	1.4820	28.5	0.	287.3	43.30	453
CUMENE	120.19	0.8618	20.0	1.4915	-96.0	0.	152.4	2.38	454
O-ETHYLTOLUENE	120.19	0.8870	0.0	1.5042	-17.0	0.	164.9	0.0	455
ISOPROPYLBENZENE	120.19	0.8575	25.0	1.4889	-96.0	0.	152.4	2.38	456
1-PHENYL PROPANE	120.19	0.8620	0.0	1.4920	-99.5	0.	159.2	0.0	457
1,2,3 TRIME BENZENE	120.19	0.8944	0.0	1.5139	-25.5	0.	176.0	0.0	458
1,2,4-TRIME BENZENE	120.19	0.8890	4.0	1.5030	-60.5	0.	169.3	0.0	459
1,2,5-TRIME BENZENE	120.19	0.8642	0.0	1.4998	-52.7	0.	164.7	0.0	460
PROPYLBENZENE	120.20	0.8620	0.0	1.4900	-99.5	0.	159.2	0.0	461
1,3,5-TRIMETHYLBENZENE	120.20	0.8642	20.0	1.4998	-52.7	0.	164.7	2.27	462
1-CHLOROHEXANE	120.62	0.8784	0.0	1.4240	-83.0	0.	132.0	0.0	463
2-CL-HEXANE	120.62	0.8694	21.0	1.4142	0.0	0.	0.0	0.0	464
3-CL-HEXANE	120.62	0.8700	20.0	1.4163	0.0	0.	0.0	0.0	465
1-BROMO-1-PROPENE	120.99	1.4133	20.0	1.4519	-116.6	0.	59.5	0.0	466
O-ETHYL ANILINE	121.18	0.9830	22.0	1.5584	-5.0	0.	209.0	0.0	467
O-METHYL TOLUIDINE	121.18	0.9769	20.0	1.5649	0.0	0.	206.0	0.0	468
2,4,6-TRIMETHYL PYRIDINE	121.18	0.9166	22.0	1.4959	0.0	754.	172.0	0.0	469
SALICYLALDEHYDE	122.13	1.1525	25.0	1.5702	-7.0	0.	196.7	13.90	470
O-METHYLANISOLE	122.16	0.9850	15.0	1.5199	0.0	0.	170.3	0.0	471
PHENETOLE	122.17	0.9605	25.0	1.5049	-29.5	0.	170.0	4.22	472
DIETHANOL SULFIDE	122.19	1.1793	25.0	1.5146	-10.0	0.	282.0	0.0	473
2-CHLOROETHYLACETATE	122.55	1.1783	6.0	1.4215	-20.0	0.	145.0	0.0	474
ETHYL CHLOROACETATE	122.55	1.1144	20.0	1.4215	-26.0	740.	144.0	0.0	475
1-CHLORO-3-PENTANOL	122.60	1.0327	25.0	1.4660	0.0	0.	173.0	0.0	476
ACETYL BROMIDE	122.96	1.6630	0.0	1.4538	-96.5	0.	76.7	0.0	477
1-BROMOPROPANE	123.00	1.3452	25.0	1.4317	-109.8	0.	71.0	8.09	478
2-BROMOPROPANE	123.00	1.3060	25.0	1.4221	-89.0	0.	59.4	9.46	479
NITROBENZENE	123.11	1.2082	15.0	1.5546	5.7	0.	210.8	34.82	480
DIETHYL ZINC	123.50	1.1820	18.0	1.4954	-28.0	0.	118.0	0.0	481
M-THIOCRESOL	124.21	1.0526	12.0	1.5752	-20.0	0.	195.4	0.0	482
BETA-CLETHYLCELLOSOLVE	124.57	0.0	19.0	1.4505	0.0	760.	182.0	0.0	483
3-CL-2-CLME-PROPENE	125.00	1.1782	20.0	1.4754	-14.0	0.	138.3	0.0	484
CAPRYLONITRILE	125.21	0.8097	25.0	1.4182	-45.6	0.	205.2	13.90	485
DIMETHYL SULFATE	126.13	1.3283	20.0	1.3874	-31.8	760.	188.5	0.0	486
2,5-DIME-CYCLOHEXANONE	126.19	0.9025	20.0	1.4446	0.0	0.	178.0	0.0	487
2-NONENE (TRANS)	126.23	0.7540	0.0	1.4191	0.0	0.	148.5	0.0	488
1-NONENE	126.24	0.7253	25.0	1.4133	-81.4	0.	146.9	0.0	489
BENZYL CHLORIDE	126.58	1.1000	0.0	1.5391	-39.0	0.	179.4	23.00	490
M-CHLOROTOLUENE	126.58	1.0722	0.0	1.5214	-47.8	0.	162.0	5.55	491
P-CHLOROTOLUENE	126.58	1.0697	0.0	1.5199	7.5	0.	162.0	6.08	492
1,2-DICL ISOBUTANE	127.01	1.0930	20.0	1.4370	-130.0	0.	108.0	0.0	493
1,1-DICHLOROBUTANE	127.02	1.0863	0.0	1.4355	0.0	763.	114.5	0.0	494
1,2-DICHLOROBUTANE	127.02	1.1116	25.0	1.4474	0.0	0.	124.0	0.0	495
1,4-DICHLOROBUTANE	127.02	1.7598	12.0	1.4566	-38.7	0.	162.0	0.0	496
2,3-DICHLOROBUTANE	127.03	1.1134	20.0	1.4420	-80.0	760.	116.0	0.0	497
1,1-DICH-2-ME PROPANE	127.03	1.0111	20.0	1.4330	0.0	760.	105.5	0.0	498
1,2-DICH-2-ME PROPANE	127.03	1.0930	20.0	1.4370	-130.0	760.	108.0	0.0	499
1,3-DICH-2-ME PROPANE	127.03	1.1325	25.0	1.4488	0.0	760.	134.6	0.0	500
1-ACETYLPIPERIDINE	127.18	1.0112	9.0	0.0	108.0	0.	226.5	0.0	501
O-CHLOROANILINE	127.57	1.2125	20.0	1.5881	-1.9	0.	208.8	13.40	502
3-ME-HEPTANONE-2	128.21	0.8318	20.0	1.4172	0.0	0.	167.0	0.0	503
2-ETHYLCYCLOHEXANOL(CIS)	128.22	0.9274	21.0	1.4655	0.0	12.	74.0	0.0	504
OCTANONE-2	128.22	0.8185	0.0	1.4161	-20.9	0.	173.0	0.0	505
OCTANONE-3	128.22	0.8220	20.0	1.4156	0.0	738.	169.0	0.0	506
ISO-NONANE	128.25	0.7134	0.0	1.4032	-80.5	0.	142.8	0.0	507
4-METHYL OCTANE	128.25	0.7199	0.0	1.4061	-119.1	0.	142.4	0.0	508
NONANE	128.25	0.7138	25.0	1.4054	-53.5	0.	150.8	1.97	509
2,2,5-TRIME HEXANE	128.25	0.7032	25.0	1.3997	-105.8	0.	124.1	0.0	510

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
DICHLOROACETIC ACID	128.94	1.5634	20.0	1.4658	10.8	0.	192.5	8.20	511
1,3-DICL-2-PROPANOL	128.99	1.3506	17.0	1.4837	0.0	760.	176.0	0.0	512
N-ACETYL MORPHOLINE	129.16	1.1165	20.0	1.4383	14.0	50.	152.0	0.0	513
CINNAMONITRILE	129.16	1.0283	20.0	1.6043	22.0	0.	263.8	0.0	514
QUINOLINE	129.16	1.0977	25.0	1.6293	-14.9	760.	237.1	9.00	515
DIBUTYLAMINE	129.25	0.7619	20.0	1.4177	-62.0	0.	159.6	2.98	516
ETHYLACETOACETATE	130.15	1.0222	20.0	1.4192	-40.0	0.	180.8	15.70	517
PROPIONIC ANHYDRIDE	130.15	1.0110	20.0	1.4045	-43.0	0.	169.0	18.30	518
N-BUTYL PROPIONATE	130.18	0.8818	0.0	1.3982	-89.5	0.	145.5	0.0	519
HEPTANOIC ACID	130.18	0.9185	0.0	1.4216	-10.0	0.	223.0	0.0	520
ISOBUTYLPROPIONATE	130.18	0.8876	20.0	1.3975	-71.4	0.	136.8	0.0	521
4(2-AMINOET)MORPHOLINE	130.19	0.9915	20.0	1.4715	25.6	50.	116.0	0.0	522
AMYL ACETATE	130.19	0.8753	20.0	1.4028	-100.0	0.	149.2	4.75	523
ETHYL ISOVALERATE	130.19	0.8652	20.0	1.3962	-99.3	0.	134.7	4.71	524
2-OCTANOL(DL)	130.22	0.8193	0.0	1.4203	-38.5	0.	180.0	0.0	525
2,2,4-TRI ME PENTANOL-4	130.22	0.8270	0.0	1.4293	-16.7	0.	194.5	0.0	526
BUTYL ETHER	130.23	0.7641	25.0	1.3968	-95.2	0.	142.2	0.0	527
2-ET-1-HEXANOL	130.23	0.8291	25.0	1.4292	-76.0	0.	184.4	4.41	528
2-ME-HEPTANOL-2	130.23	0.8142	20.0	1.4279	0.0	0.	156.0	0.0	529
3-ME-HEPTANOL-3	130.23	0.8282	20.0	1.4238	-83.0	0.	163.0	0.0	530
1-OCTANOL	130.23	0.8221	25.0	1.4275	-15.0	0.	195.2	10.34	531
P-FLUORO CHLORO BENZENE	130.55	1.2260	0.0	1.4990	-28.3	757.	130.0	0.0	532
TRIMETHYL BORATE	130.92	0.9200	23.0	1.3568	-34.0	0.	69.0	0.0	533
ISOAMYL ACETATE	130.98	0.8664	25.0	1.3984	78.5	0.	42.0	4.63	534
4(B-HYDROXYET)MORPHOLINE	131.17	1.0710	20.0	1.4780	0.0	757.	227.0	0.0	535
1-NITROHEXANE	131.17	0.0	0.0	1.4229	0.0	0.	0.0	0.0	536
TRICHLOROETHYLENE	131.39	1.4762	15.0	1.4800	-86.4	0.	87.2	3.42	537
DIMETHYLMALONATE	132.11	1.1544	0.0	1.4140	-80.0	0.	183.0	0.0	538
CELLOSOLVE ACETATE	132.16	0.9730	20.0	1.4050	-61.7	0.	156.3	7.57	539
CINNAMALDEHYDE	132.16	1.0497	20.0	1.6195	-75.0	760.	253.0	16.90	540
1234TET H NAPHTHALENE	132.21	0.9702	20.0	1.5414	-35.8	0.	207.6	2.77	541
1234TET H NAPHTHALENE	132.21	0.9662	25.0	1.5492	-35.8	0.	207.6	2.77	542
1-FLUORO OCTANE	132.22	0.8103	0.0	1.3935	0.0	0.	142.5	0.0	543
ETHYLDIETHANOLAMINE	133.19	1.0135	20.0	1.4663	-50.0	760.	247.0	0.0	544
1,1,1-TRICHLOROETHANE	133.41	1.3376	20.0	1.4379	-30.4	0.	74.0	7.53	545
1,1,2-TRICL ETHANE	133.41	1.4405	20.0	1.4706	-37.4	0.	113.0	0.0	546
3-BR PROPIONITRILE	133.98	1.6152	20.0	1.1470	0.0	25.	92.0	0.0	547
ALLYL PHENYL ETHER	134.18	0.9788	25.0	1.5200	0.0	18.	85.0	0.0	548
CARBITOL	134.18	0.9881	0.0	1.4273	0.0	0.	201.0	0.0	549
CINNAMYL ALCOHOL	134.18	1.0440	20.0	1.5819	33.0	0.	257.5	0.0	550
2-(2-ETOETO)ETHANOL	134.18	0.9814	25.0	1.4254	0.0	0.	202.0	0.0	551
BIS(2-MEOET) ETHER	134.18	0.9440	25.0	1.4043	0.0	0.	159.8	0.0	552
1-PHENYL-2-PROPANONE	134.18	1.0157	20.0	1.5168	27.0	0.	216.5	0.0	553
PROPIOPHENONE	134.18	1.0105	20.0	1.5269	18.6	0.	218.0	0.0	554
O-DIETHYLBENZENE	134.21	0.8800	0.0	1.5035	-20.0	0.	183.0	0.0	555
1,3-DIETHYLBENZENE	134.21	0.8639	20.0	1.4955	-20.0	0.	181.0	0.0	556
1,4-DIETHYLBENZENE	134.21	0.8620	20.0	1.4967	-35.0	0.	182.0	0.0	557
P-ISOPROPYL TOLUENE	134.21	0.8569	0.0	1.4904	0.0	0.	177.0	0.0	558
1234 TETRA-ME-BENZENE	134.21	0.9010	0.0	1.5187	-64.0	0.	203.5	0.0	559
1235 TETRA-ME-BENZENE	134.21	0.8906	0.0	1.5134	-24.0	0.	196.0	0.0	560
BUTYL BENZENE	134.22	0.8561	25.0	1.4874	-87.9	0.	183.3	2.36	561
SEC-BUTYL BENZENE	134.22	0.8580	25.0	1.4878	-75.5	0.	173.3	2.36	562
P-CYMENE	134.22	0.8533	25.0	1.4885	-67.9	0.	177.1	2.25	563
TERT-BUTYL BENZENE	134.22	0.8624	25.0	1.4902	-57.9	0.	169.1	2.37	564
4-CHLOROCYCLOHEXANOL	134.61	1.1435	17.0	1.4930	0.0	14.	106.0	0.0	565
1-CHLOROHEPTANE	134.65	0.8810	0.0	1.4248	-69.0	0.	158.0	0.0	566
2-CL-HEPTANE	134.65	0.8725	15.0	1.4221	0.0	19.	46.0	0.0	567
3-CL-HEPTANE	134.65	0.8960	20.0	1.4237	0.0	751.	144.0	0.0	568
4-CL-HEPTANE	134.65	0.8710	20.0	1.4237	0.0	758.	144.0	0.0	569
4-BROMO-1-BUTENE	135.01	1.3230	20.0	1.4622	0.0	758.	98.5	0.0	570
BENZEDRINE	135.20	0.9400	15.0	1.5463	0.0	0.	203.5	0.0	571
PHENYL ACETATE	136.14	1.0730	25.0	1.5051	0.0	765.	195.8	18.40	572
BENZYL FORMATE	136.15	1.0817	25.0	1.5121	0.0	20.	93.0	0.0	573
METHYL BENZOATE	136.15	1.0790	30.0	1.5123	-12.1	0.	199.5	6.59	574
N-PROPYL PHENYL ETHER	136.19	0.9530	15.0	1.5011	0.0	0.	189.5	0.0	575
BENZYL ETHYL ETHER	136.20	0.9446	25.0	1.4934	0.0	0.	185.0	3.90	576
3-PHENYL-1-PROPANOL	136.20	1.0080	20.0	1.5357	-18.0	750.	236.5	0.0	577
ALPHA PINENE	136.24	0.8539	25.0	1.4632	-64.0	0.	156.9	2.26	578
BETA PINENE	136.24	0.8667	25.0	1.4768	-61.5	0.	166.0	2.50	579
ETHYL CHLOROGLYOXYLATE	136.54	1.2226	20.0	0.0	0.0	760.	135.0	0.0	580
6-CL-HEXANOL-1	136.62	0.0	0.0	1.4531	0.0	12.	107.0	0.0	581
BROMOBUTANE	137.03	1.2764	20.0	1.4389	-112.4	0.	101.3	0.0	582
2-BROMO-2-ME PROPANE	137.03	1.2220	20.0	1.4283	-20.0	0.	73.3	0.0	583
1-BROMO-2-ME PROPANE	137.03	1.3356	25.0	1.4348	0.0	0.	91.0	0.0	584
DIETHYL SELENIDE	137.06	1.2300	20.0	1.4768	0.0	0.	108.0	0.0	585
ANILINOETHANOL	137.18	1.1129	25.0	1.5749	0.0	0.	286.0	0.0	586
METHOXY BENZYL ALCOHOL	138.16	1.0430	25.0	1.5490	0.0	0.	249.0	0.0	587
2-PHENOXYETHANOL	138.17	1.1020	22.0	1.5340	14.0	0.	237.0	0.0	588
VERATROLE	138.17	1.0819	25.0	1.5323	22.5	0.	206.3	4.09	589
DIETHYL SULFITE	138.19	1.0829	20.0	1.4144	0.0	768.	157.0	0.0	590
ISOPHORONE	138.21	0.9229	20.0	1.4759	-8.1	754.	214.0	0.0	591
DECAHYDRONAPHTHALENE	138.24	0.8789	25.0	1.4758	-125.0	0.	191.7	0.0	592
CIS-DECAHYDRONAPHTHALENE	138.24	0.8967	0.0	1.4811	-43.3	0.	195.7	0.0	593
TRAN-DECAHYDRONAPTHALENE	138.24	0.8700	0.0	1.4696	-32.5	0.	187.3	0.0	594
BROMOACETIC ACID	138.95	1.9335	50.0	1.4804	5.0	760.	208.0	0.0	595

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
1-PHENYL-2-PROPANOL	139.20	0.9727	19.0	1.5314	36.0	0.	217.0	0.0	596
PELARGONIC NITRILE	139.23	0.7860	16.0	1.4235	-34.2	0.	224.0	0.0	597
DECAHYDROQUINOLINE	139.24	0.9426	20.0	1.4926	-40.0	20.	90.0	0.0	598
TRIMETHYLPHOSPHATE	140.08	1.2144	20.0	1.3967	-46.0	760.	197.2	0.0	599
2-ACETYL CYCLOHEXANONE	140.18	1.0782	20.0	1.5138	0.0	18.	112.0	0.0	600
2-ISOPROPYLCYCLOHEXANONE	140.23	0.9270	20.0	1.4538	0.0	76.	199.0	0.0	601
BUTYLCYCLOHEXANE	140.27	0.8178	20.0	1.4400	-78.6	0.	179.0	0.0	602
1-DECENE	140.27	0.7369	25.0	1.4191	-66.3	0.	170.6	0.0	603
1,5-DICHLOROPENTANE	141.04	1.1006	20.0	1.4564	-72.8	760.	180.0	0.0	604
IODOMETHANE	141.94	2.2649	25.0	1.5270	-66.5	0.	42.4	7.00	605
1-ACETYL CYCLOHEXANOL	142.20	1.0257	20.0	1.4726	0.0	50.	125.0	0.0	606
1-METHYL NAPHTHALENE	142.20	1.0202	20.0	1.6170	-22.0	760.	244.6	0.0	607
METHYL HEPTYL KETONE	142.23	0.8185	0.0	1.4161	-20.9	0.	173.0	0.0	608
4-NONANONE	142.24	0.8370	20.0	1.4210	0.0	0.	187.5	0.0	609
5-NONANONE	142.24	0.8270	20.0	1.3980	-4.8	0.	188.4	0.0	610
3,3,5-TRIME CYCLOHEXANOL	142.24	0.9006	16.0	1.4550	37.3	750.	202.0	0.0	611
DECANE	142.27	0.7262	25.0	1.4119	-29.7	0.	174.1	1.99	612
METHYL-DICHLORO ACETATE	142.97	1.3774	20.0	1.4429	-51.9	760.	142.8	0.0	613
BIS(2-CL ETHYL)ETHER	143.01	1.2192	20.0	1.4575	-46.8	0.	178.8	21.20	614
1,3-DICL-2-ME-2-PROPANOL	143.02	1.2758	20.0	1.4744	0.0	0.	174.5	0.0	615
2-METHYL QUINOLINE	143.18	1.0585	0.0	1.6126	-1.0	0.	246.5	0.0	616
TRI-N-PROPYL AMINE	143.27	0.7530	25.0	1.4176	-93.5	0.	156.0	0.0	617
1-BR-2-CL-ETHANE	143.43	1.7392	20.0	1.4917	-16.7	0.	107.0	0.0	618
DIMETHYL MALEATE	144.13	1.1513	20.0	1.4422	-17.5	0.	200.4	0.0	619
TETRAHYDROFURFURYL ACET	144.17	1.0672	25.0	1.4352	0.0	14.	85.0	0.0	620
4(3-AMINOPROP)MORPHOLINE	144.21	0.9872	20.0	1.4749	-15.0	50.	134.0	0.0	621
AMYLPROPIONATE	144.21	0.8760	0.0	1.4096	-73.1	760.	168.7	0.0	622
BUTYLBUTYRATE (N)	144.21	0.8717	20.0	1.4045	-91.5	760.	166.6	0.0	623
ISOBUTYL-N-BUTYRATE	144.21	0.8364	18.0	1.4030	0.0	0.	157.0	0.0	624
N-PROPYL VALERATE	144.21	0.8888	0.0	1.4057	0.0	0.	167.5	0.0	625
CAPRYLIC ACID	144.22	0.9106	20.0	1.4280	16.5	0.	239.9	2.45	626
2-ETHYLBUTYL ACETATE	144.22	0.8790	20.0	1.4109	-100.0	760.	162.5	0.0	627
HEXYL ACETATE	144.22	0.8779	15.0	1.4092	-80.9	760.	171.5	0.0	628
ISOBUTYLISOBUTYRATE	144.22	0.8742	20.0	1.3999	-80.7	0.	147.5	0.0	629
ISOBUTYLISOBUTYRATE	144.22	0.8489	25.0	1.3981	-80.7	0.	175.6	0.0	630
NONYL ALCOHOL	144.25	0.8273	0.0	1.4333	-5.0	0.	212.0	0.0	631
2,6-DIMETHYL-4-HEPTANOL	144.26	0.8090	21.0	1.4242	0.0	760.	176.5	0.0	632
SILICONANE	144.34	0.7682	0.0	1.4243	0.0	0.	154.7	0.0	633
4-PHENYLBUTRONITRILE	145.21	0.9762	0.0	1.5150	0.0	0.	139.0	0.0	634
3,3,3-TRICHLOROPROPENE	145.43	1.3690	20.0	1.4827	30.0	0.	104.5	0.0	635
DIETHYL OXALATE	146.14	1.0669	30.0	1.4060	-40.6	0.	185.4	1.80	636
ETHYLENE DIACETATE	146.14	1.1043	20.0	1.4159	-41.5	0.	190.9	10.00	637
BUTYL LACTATE DL	146.19	0.9803	22.0	1.4217	-43.0	13.	83.0	0.0	638
2-ETHYL-1,3-HEXANEDIOL	146.23	0.9325	22.0	1.4497	-40.0	760.	244.0	0.0	639
HEXYL CELLOSOLVE	146.23	0.8894	20.0	1.4291	-45.1	760.	208.0	0.0	640
TRIETHYLENETETRAMINE	146.24	0.9820	20.0	1.4971	12.0	760.	266.5	0.0	641
O-DICHLOROBENZENE	147.01	1.3059	20.0	1.5515	-17.0	0.	180.5	9.93	642
M-DICHLOROBENZENE	147.01	1.2884	20.0	1.5459	-24.8	0.	173.0	5.04	643
P-DICHLOROBENZENE	147.01	1.2416	60.0	1.5285	53.1	0.	174.1	2.41	644
KAIROLINE	147.21	1.0220	0.0	1.5082	0.0	758.	0.0	0.0	645
1-PHENYL-PYRROLIDINE	147.22	1.0260	25.0	1.5803	0.0	9.	113.0	0.0	646
TRICHLOROACETALDEHYDE	147.40	1.5120	0.0	1.4557	-57.5	0.	98.0	0.0	647
1,1,1-TRICHLOROPROPANE	147.43	1.2870	23.0	0.0	0.0	760.	107.5	0.0	648
1,1,2-TRICHLOROPROPANE	147.43	1.3720	25.0	0.0	0.0	760.	140.0	0.0	649
1,1,3-TRICHLOROPROPANE	147.43	1.3557	20.0	1.4718	-59.0	760.	145.6	0.0	650
1,2,2-TRICHLOROPROPANE	147.43	1.3180	25.0	1.4609	0.0	762.	124.0	0.0	651
1,2,3-TRICHLOROPROPANE	147.44	1.3940	0.0	1.4858	-14.7	0.	156.0	0.0	652
BUTYROPHENONE	148.20	0.9880	0.0	1.5320	11.0	727.	231.0	0.0	653
1 PHENYLPENTANE	148.24	0.8662	0.0	1.4943	-78.3	0.	205.3	0.0	654
1-CHLORO OCTANE	148.67	0.8748	0.0	1.4306	0.0	765.	181.0	0.0	655
1-CL-2,5-DIME HEXANE	148.68	0.8476	18.0	1.4232	0.0	14.	44.0	0.0	656
2-BR-3-ME-1-BUTENE	149.04	1.2328	20.0	1.4504	0.0	757.	105.0	0.0	657
1-BR-3-ME-2-BUTENE	149.04	1.2819	20.0	1.4930	0.0	40.	50.5	0.0	658
2-BR-3-ME-2-BUTENE	149.04	1.2773	20.0	1.4738	0.0	766.	119.5	0.0	659
TRIETHANOLAMINE	149.19	1.1196	25.0	1.4835	21.6	0.	335.4	29.36	660
N-BUTYLANILINE	149.24	0.9323	20.0	1.5341	-14.4	760.	241.6	0.0	661
2,2,2-TRICHLOROETHANOL	149.42	1.5521	25.0	1.4890	17.8	737.	151.0	0.0	662
BENZYL ACETATE	150.18	1.0550	20.0	1.5232	-51.5	0.	215.5	5.10	663
ETHYL BENZOATE	150.18	1.0511	15.0	1.5075	-34.7	0.	212.4	6.02	664
TRIETHYLENE GLYCOL	150.18	1.1274	15.0	1.4578	-4.3	0.	288.0	23.69	665
N-BUTYL PHENYL ETHER	150.21	0.9351	0.0	1.4969	-19.0	0.	210.0	0.0	666
2-ME-1-PHENYLPROPANOL-1	150.22	0.9869	14.0	1.5193	0.0	0.	223.0	0.0	667
2-ME-1-PHENYLPROPANOL-2	150.22	0.9774	19.0	1.5201	24.0	0.	215.0	0.0	668
4-CHLOROBUTYL ACETATE	150.61	1.0759	0.0	1.4340	0.0	0.	83.0	0.0	669
1-BROMO-3-ME BUTANE	151.05	1.2609	20.0	1.4420	-112.0	0.	120.0	0.0	670
1-BROMOPENTANE	151.05	1.2177	0.0	1.4413	-95.0	0.	129.7	0.0	671
ET-2-PYRIDINECARBOXYLATE	151.16	1.1194	20.0	1.5104	1.0	0.	243.0	0.0	672
METHYL SALICYLATE	152.15	1.1831	20.0	1.5365	-8.6	0.	233.3	9.41	673
2-BENZYLOXYETHANOL	152.20	1.0640	20.0	1.5233	-75.0	760.	256.0	0.0	674
CINNAMYL CHLORIDE	152.63	0.0	0.0	0.0	-19.0	0.	214.0	0.0	675
BROMOMETHYLACETATE	152.99	1.6560	12.0	0.0	0.0	750.	130.0	0.0	676
O-NITROANISOLE	153.14	1.2527	20.0	1.5619	10.5	0.	265.0	0.0	677
CARBON TETRACHLORIDE	153.82	1.6037	15.0	1.4631	-23.0	0.	76.7	2.24	678
CARBON TETRACHLORIDE	153.82	1.5844	25.0	1.4574	-23.0	0.	76.7	2.24	679
DIETHYL SULFATE	154.19	1.1774	20.0	1.4004	-24.5	0.	208.0	0.0	680

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
1,8-CINEOLE	154.25	0.9192	25.0	1.4555	1.3	0.	176.0	4.57	681
2-NBUTYLCYCLOHEXANONE	154.28	0.9350	20.0	1.4545	0.0	2.	7.0	0.0	682
1-UNDECENE	154.29	0.7506	0.0	1.4261	-50.0	0.	193.0	0.0	683
SUCCINYL CHLORIOE	154.98	1.3748	20.0	1.4683	20.0	760.	193.3	0.0	684
1,6-DICL-HEXANE	155.08	1.0677	20.0	1.4572	0.0	0.	202.4	0.0	685
IODOETHANE	155.97	1.9357	20.0	1.5133	-111.1	0.	72.3	7.82	686
3-CYCLOHEXPROPANOIC ACID	156.22	0.9966	20.0	1.4658	16.0	750.	193.0	0.0	687
1-ETHYL NAPHTHALENE	156.23	1.0082	20.0	1.6062	-13.9	760.	258.7	0.0	688
2-ETHYL NAPHTHALENE	156.23	0.9922	20.0	1.5999	-7.4	760.	257.9	0.0	689
DECANONE-2	156.26	0.8230	22.0	1.4621	14.0	767.	210.5	0.0	690
2-BUTYLCYCLOHEXANOL	156.27	0.9020	20.0	1.4641	0.0	3.	75.0	0.0	691
3-ISOPRO-2-HEPTANONE	156.27	0.8195	20.0	1.4250	0.0	0.	78.0	0.0	692
UNDECANE	156.30	0.7401	0.0	1.4172	-25.0	0.	195.5	2.01	693
BETA-CHLOROPHENETOLE	156.61	1.1443	25.0	1.5328	0.0	0.	0.0	0.0	694
P-CHLOROPHENETOLE	156.61	1.1231	20.0	1.5227	21.0	0.	213.0	0.0	695
2-CLETHYLCHLORDACETATE	157.00	1.3600	25.0	1.4619	0.0	760.	202.0	0.0	696
2,3-DICHLORODIOXANE	157.00	1.4680	20.0	1.4928	30.0	10.	81.0	0.0	697
ETHYLDICHLOROACETATE	157.00	1.2821	20.0	1.4386	0.0	0.	157.0	10.00	698
BROMOBENZENE	157.02	1.4882	25.0	1.5571	-30.8	0.	155.9	5.40	699
DIPENTYLAMINE	157.30	0.7771	20.0	1.4272	-70.0	760.	202.5	0.0	700
ALLYLIDENE DIACETATE	158.15	1.0749	20.0	1.4193	-37.6	0.	180.0	0.0	701
TETRAHYDROFURFURYL PROP	158.19	1.0321	25.0	1.4380	0.0	18.	101.0	0.0	702
BUTYRIC ANHYDRIDE	158.20	0.9668	20.0	1.4127	-66.7	0.	199.5	12.90	703
HEXYL PROPIONATE	158.23	0.8698	20.0	0.0	57.5	0.	190.0	0.0	704
ISOAMYL ETHER	158.27	0.7777	20.0	1.4085	0.0	0.	173.4	0.0	705
AMYL ETHER	158.28	0.7790	25.0	1.4098	-69.4	0.	186.9	0.0	706
DIETHYL MALONATE	160.17	1.0549	20.0	1.4136	-48.9	0.	199.3	7.87	707
CYCLOHEXYLBENZENE	160.26	0.9387	25.0	1.5239	7.0	0.	240.1	0.0	708
1-CHLOROPENTANE	160.60	0.8818	20.0	1.4120	-99.0	0.	107.7	6.60	709
BENZAL CHLORIDE	161.03	1.2557	14.0	1.5502	-16.4	0.	205.2	0.0	710
N-BUTYLDIETHANOLAMINE	161.25	0.9692	20.0	1.4625	-70.0	741.	274.0	0.0	711
1,2,3-TRICHLORO BUTANE	161.46	1.3164	20.0	1.4790	0.0	725.	166.5	0.0	712
2-ME-1,2,3-TRICL PROPANE	161.47	1.3012	25.0	1.4765	0.0	0.	162.0	0.0	713
ISOSAFROLE	162.18	1.1140	25.0	1.5740	0.0	0.	0.0	0.0	714
SAFROLE	162.18	1.0950	25.0	1.5383	11.2	0.	233.5	0.0	715
DIETHYLENEGLYCOIET ETHER	162.22	1.9063	0.0	1.4115	0.0	0.	188.0	0.0	716
BUTYLCARBITOL	162.23	0.9553	20.0	1.4321	-68.1	760.	231.0	0.0	717
1,2,4-TRIETHYL BENZENE	162.27	0.8738	0.0	1.5024	0.0	0.	218.0	0.0	718
1,3,5-TRIETHYL BENZENE	162.27	0.8621	0.0	1.4958	-66.5	755.	216.0	0.0	719
1-PHENYLHEXANE	162.28	0.8540	0.0	1.4860	-62.0	760.	226.0	0.0	720
2-CHLORONAPHTHALENE	162.61	1.1377	71.0	1.6079	59.0	0.	256.0	0.0	721
1-CHLORONAPHTHALENE	162.62	1.1938	20.0	1.6332	-2.3	0.	259.3	5.04	722
TRICHLOROACETIC ACID	163.39	1.6218	64.0	1.4603	5.8	760.	197.6	0.0	723
2-CHLOROQUINOLINE	163.60	1.2464	25.0	1.6259	37.5	751.	275.0	0.0	724
DICHLOROBROMOMETHANE	163.85	1.9800	20.0	1.4964	0.0	742.	89.5	0.0	725
4-PHENYL-1,3-DIOXANE	164.19	1.1038	20.0	1.5306	0.0	0.	245.0	0.0	726
EUGENOL	164.20	1.0664	20.0	1.5410	9.2	760.	255.0	0.0	727
PROPYL BENZOATE	164.21	1.0232	20.0	1.5003	-51.6	0.	231.2	0.0	728
BENZYL BUTYL ETHER	164.25	0.9407	20.0	1.4970	15.0	744.	220.5	0.0	729
NITROTRICHLORO METHANE	164.38	1.6566	20.0	1.4622	-64.5	760.	111.8	0.0	730
1-BROMOHEXANE	165.08	1.1763	20.0	1.4478	-85.0	0.	154.0	0.0	731
2-BR-HEXANE	165.08	1.1658	20.0	1.4432	0.0	0.	144.0	0.0	732
3-BR-HEXANE	165.08	1.1799	20.0	1.4486	0.0	744.	144.0	0.0	733
TETRACHLOROETHYLENE	165.83	1.6311	15.0	1.5076	-22.3	0.	121.2	2.30	734
BICYCLOHEXYL	166.31	0.8862	20.0	1.4800	3.6	0.	239.0	0.0	735
2-BROMOETHYLACETATE	167.02	1.5140	20.0	1.4547	-13.8	0.	162.5	0.0	736
1122-TET CL ETHANE	167.85	1.5786	30.0	1.4868	-43.8	0.	146.2	8.20	737
1112 TET CL ETHANE	167.86	1.5532	0.0	1.4821	-68.1	0.	129.5	0.0	738
3-IODOPROPENE	167.99	1.8454	22.0	1.5540	-99.3	0.	102.5	0.0	739
O-PHENYL TOLUENE	168.23	1.0100	0.0	1.6824	45.0	0.	262.5	0.0	740
2-BENZYL PYRIDINE	169.23	1.0670	20.0	1.5785	12.0	742.	276.0	0.0	741
1-IODOPROPANE	170.00	1.7394	25.0	1.5028	-101.3	0.	102.4	7.00	742
2-IODOPROPANE	170.00	1.6946	25.0	1.4961	-90.0	0.	89.5	8.19	743
1-ACETONAPHTHANE	170.21	1.1336	20.0	1.6280	12.0	0.	297.0	0.0	744
DIPHENYL ETHER	170.21	1.0661	30.0	1.5763	26.9	0.	258.3	3.69	745
DODECANE	170.34	0.7487	20.0	1.4216	-9.6	0.	216.3	2.01	746
BENZYL CHLOROFORMATE	170.60	1.1950	25.0	1.5160	0.0	0.	0.0	0.0	747
M-BROMOTOLUENE	171.04	1.4019	20.0	1.5510	-39.8	0.	183.7	5.36	748
P-BROMOTOLUENE	171.04	1.3898	20.0	1.5490	28.5	0.	184.5	5.49	749
B,B'DICL-DIISOPROP ETHER	171.07	1.1030	20.0	1.4505	0.0	0.	187.0	0.0	750
DIETHYL MALEATE	172.18	1.0687	20.0	1.4400	-8.8	0.	225.3	8.58	751
1-ETHOXY NAPHTHALENE	172.23	1.0600	20.0	1.5953	5.5	0.	280.5	0.0	752
HEPTYL PROPIONATE	172.26	0.8679	20.0	0.0	-50.9	0.	209.0	0.0	753
2-ETHYLHEXYL ACETATE	172.27	0.8718	20.0	1.4204	-93.0	0.	198.6	0.0	754
UNDECYL ALCOHOL	172.30	0.8298	0.0	1.4392	19.0	760.	243.0	0.0	755
2-UNDECANOL	172.31	0.8270	20.0	1.4369	12.0	760.	225.4	0.0	756
O-BROMOPHENOL	173.02	1.4924	20.0	1.5892	5.6	0.	194.5	0.0	757
METHYLENE BROMIDE	173.85	2.4970	20.0	1.5420	-52.6	760.	97.0	7.50	758
DIETHYL SUCCINATE	174.19	1.0406	20.0	1.4201	-22.0	0.	217.7	0.0	759
N-DIPROPYL OXALATE	174.19	1.0169	0.0	1.4168	-46.3	0.	214.5	0.0	760
DIMETHYL ADIPATE	174.20	1.0600	20.0	1.4283	10.3	13.	115.0	0.0	761
DIBUTOXYETHANE	174.28	0.8370	0.0	1.4131	-69.0	0.	203.0	0.0	762
P-FLUORO BROMOBENZENE	175.01	1.4946	0.0	1.5604	-17.0	764.	152.0	0.0	763
N-OCTYL NITRATE	175.22	0.9750	0.0	0.0	0.0	20.	111.0	0.0	764
2-(2-ETOETO)ETACETATE	176.21	1.0096	20.0	1.4213	-25.0	0.	217.4	0.0	765

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
ETHYL CINNAMATE	176.21	1.0494	20.0	1.5598	6.7	0.	272.7	0.0	766
1-CHLORODECANE	176.73	0.8663	0.0	1.4373	0.0	0.	222.5	0.0	767
ISOAMYLISOVALERATE	177.26	0.8583	18.7	1.4130	0.0	0.	194.0	3.62	768
METHYL TRICL ACETATE	177.43	1.4890	19.2	1.5250	-17.5	765.	152.5	0.0	769
BENZYL BUTYRATE	178.23	1.0140	19.0	1.4920	9.0	0.	109.0	0.0	770
TETRAMETHYL TIN	178.83	1.3140	0.0	1.4386	-54.8	0.	78.0	0.0	771
1-BROMOHEPTANE	179.11	1.1384	20.0	1.4505	-58.0	0.	179.0	0.0	772
HEXAME PHOSPHORAMIDE	179.20	1.0270	20.0	1.4588	7.2	0.	233.0	30.00	773
(ISO)PROPYL SALICYLATE	180.20	1.0729	15.0	1.5065	0.0	0.	241.0	0.0	774
1,4-(BIS CL ME)CYC HEX	181.11	1.1180	25.0	1.4908	15.0	0.	121.0	0.0	775
1,2,4-TRICL BENZENE	181.45	1.4542	20.0	1.5717	17.0	760.	213.5	0.0	776
1112TETRACLPROPANE	181.89	1.4695	22.0	1.4855	-64.0	0.	152.5	0.0	777
1,1-DIPHENYLETHANE	182.27	0.9875	20.0	1.5761	-215.0	0.	286.0	0.0	778
1,2-DIPHENYLETHANE	182.27	0.9950	20.0	1.5338	52.2	0.	285.0	0.0	779
TERT-BUTYL IODIDE	184.02	1.5445	20.0	1.4918	-38.2	0.	108.0	0.0	780
1-IODOBUTANE	184.03	1.6123	0.0	1.5000	-103.1	0.	130.0	0.0	781
N-TRIDECANE	184.37	0.7559	0.0	1.4233	-5.5	0.	243.0	0.0	782
BENZYL CHLOROACETATE	184.63	1.2223	4.0	1.5426	10.0	0.	133.3	0.0	783
TRI-N-BUTYLAMINE	185.36	0.7771	20.0	1.4297	-70.0	760.	213.0	0.0	784
TRIBUTYL AMINE (ISO)	185.36	0.7640	20.5	1.4252	-21.8	0.	191.5	0.0	785
CIS-1,2-DIBR ETHYLENE	185.80	2.2464	20.0	1.5428	-53.0	760.	112.5	0.0	786
TRANS-1,2-DIBR ETHYLENE	185.80	2.2308	20.0	1.5505	-6.5	760.	108.0	0.0	787
2-BROMO-4-ME ANILINE	186.06	1.4745	25.0	1.6012	15.0	0.	0.0	0.0	788
HEXAFLUOROBENZENE	186.06	1.6182	20.0	1.3781	5.1	0.	80.3	0.0	789
OCTYL PROPIONATE	186.29	0.8663	0.0	0.0	0.0	0.	0.0	0.0	790
DIHEXYL ETHER	186.34	0.7936	20.0	1.4204	-43.0	768.	223.0	0.0	791
BIS(2-CL ET) CARBONATE	187.02	1.3444	25.0	1.4595	10.0	0.	117.0	0.0	792
112TRIFL-122TRICLETHANE	187.38	1.5635	25.0	1.3557	-36.4	0.	47.7	0.0	793
1,1-DIBROMOETHANE	187.87	2.0554	0.0	1.5122	-63.0	0.	110.0	0.0	794
1,2-DIBROMOETHANE	187.87	2.1687	25.0	1.5360	9.8	0.	131.4	4.78	795
1245 TETRAETHYL BENZENE	190.32	0.8788	0.0	1.5054	10.0	0.	250.0	0.0	796
ETHLYTRICL ACETATE	191.44	1.3826	20.0	1.4507	0.0	0.	167.5	7.80	797
ETHYL BENZOYL ACETATE	192.21	1.1220	20.0	1.5312	0.0	14.	165.0	0.0	798
3-BROMOMETHYL HEPTANE	193.13	1.1227	25.0	1.4548	0.0	0.	57.0	6.00	799
1-BROMO OCTANE	193.13	1.1180	0.0	1.4527	-55.0	0.	202.3	0.0	800
METHYL BENZOPHENONE	193.24	1.1464	0.0	1.6738	-18.0	0.	325.0	0.0	801
DIMETHYL PHTHALATE	194.18	1.1905	20.7	1.5150	0.0	0.	283.0	0.0	802
METHYL PHTHALATE	194.18	1.1890	25.0	1.5150	0.0	734.	283.0	0.0	803
TETRAETHYLENE GLYCOL	194.22	1.1285	0.0	1.4598	-6.2	0.	328.0	0.0	804
PHENYL CHLOROFORM	195.48	1.3800	0.0	1.5011	-4.8	0.	220.7	0.0	805
TETRANITROMETHANE	196.04	1.6372	0.0	1.4398	13.0	0.	126.0	0.0	806
1-TETRADECENE	196.38	0.7852	0.0	1.4932	-12.0	0.	246.0	0.0	807
DIBENZYLAMINE	197.28	1.0256	22.0	1.5143	-26.0	250.	270.0	3.60	808
1-IODOPENTANE	198.06	1.5170	0.0	1.4955	73.1	0.	155.0	0.0	809
BENZYL ETHER	198.27	1.0428	20.0	1.5406	36.0	0.	288.3	0.0	810
TRICHLOROBROMOMETHANE	198.30	2.0120	0.0	1.5061	-21.0	0.	104.0	0.0	811
N-TETRADECANE	198.40	0.7627	0.0	1.4290	6.0	0.	253.5	0.0	812
PHENYL-N-PROPYL BROMIDE	199.09	1.3098	19.0	1.5517	0.0	0.	121.5	0.0	813
(3-BROMOPROPYL)BENZENE	199.10	1.3098	19.0	1.5517	0.0	0.	121.5	0.0	814
BIS(4-CL BUTYL) ETHER	199.12	1.0796	25.0	1.4800	0.0	10.	130.0	0.0	815
2,3-DIBROMOPROPENE	199.88	2.0346	25.0	1.5416	0.0	760.	141.0	0.0	816
TRIBUTYL CARBINOL	200.35	0.8408	0.0	1.4445	20.0	0.	230.0	0.0	817
O-BROMOPHENETOLE	201.07	1.4105	25.0	1.5532	0.0	22.	124.0	0.0	818
P-BROMOPHENETOLE	201.07	1.4031	25.0	1.5498	11.0	0.	233.0	0.0	819
1,1-DIBROMOPROPANE	201.91	0.0	0.0	1.5100	0.0	74.	135.4	0.0	820
1,2-DIBROMOPROPANE	201.91	1.9366	0.0	1.5206	-55.5	0.	141.4	0.0	821
1,3-DIBROMOPROPANE	201.91	1.9893	0.0	1.5230	-34.2	0.	0.0	0.0	822
ACETYLDIMETHYLMALONATE	202.20	1.0830	26.0	1.4374	0.0	0.	120.0	0.0	823
DIBUTYL OXALATE	202.25	0.9873	20.0	1.4234	-30.5	773.	242.0	0.0	824
DIETHYLADIPATE	202.25	1.0076	20.0	1.4272	-19.8	760.	245.0	0.0	825
PENTACHLOROETHANE	202.30	1.6881	15.0	1.5054	-29.0	0.	162.0	3.73	826
1122TETCLOIF ETHANE	203.83	1.6252	35.0	1.4083	26.0	0.	92.8	2.52	827
IODOBENZENE	204.01	1.8230	25.0	1.6197	-31.4	0.	189.0	0.0	828
N,N-DIBUTYLANILINE	205.34	0.9037	20.0	1.5186	-32.2	760.	274.8	0.0	829
1-BROMONAPHTHALENE	207.08	1.4834	20.0	1.6580	6.2	0.	281.1	4.83	830
1-BROMONONANE	207.16	1.0851	25.0	1.4520	0.0	5.	84.0	0.0	831
2-BROMO-NONANE	207.16	1.0810	0.0	1.4519	0.0	767.	208.5	0.0	832
1,10-DICHLORODECANE	211.18	0.9936	0.0	1.4600	0.0	0.	148.0	0.0	833
BENZYL BENZOATE	212.25	1.1121	25.0	1.5681	19.4	0.	323.5	4.90	834
N-PENTADECANE	212.41	0.7689	0.0	1.4315	10.0	0.	270.5	0.0	835
3-BRPROPYL PHENYL ETHER	215.10	1.3650	16.0	0.0	11.0	18.	127.0	0.0	836
2-NITRO-DIPHENYL ETHER	215.21	1.2539	22.0	1.5750	-20.0	8.	184.0	0.0	837
1,2-DIBROMOBUTANE	215.94	1.7950	0.0	1.5500	0.0	0.	166.3	0.0	838
1,4-DIBROMOBUTANE	215.94	1.8080	0.0	1.5175	-26.0	0.	197.5	0.0	839
2,3-DIBROMOBUTANE	215.94	1.7830	0.0	1.5133	-70.3	0.	161.0	0.0	840
1,2-DIBR-2-ME PROPANE	215.94	1.7590	20.0	1.5090	10.5	760.	150.0	0.0	841
METHYLENE IODIDE	217.87	3.3254	0.0	1.7559	6.0	0.	181.0	0.0	842
2,3-DIBR-1-PROPANOL	217.90	2.0739	20.0	1.5466	0.0	17.	118.0	0.0	843
O-IODOTOLUENE	218.05	1.7130	0.0	1.6090	0.0	0.	211.5	0.0	844
GLYCEROL TRIACETATE	218.21	1.1562	20.0	1.5064	3.2	0.	259.0	0.0	845
PENTAETHYL BENZENE	218.37	0.8985	19.0	1.5127	-20.0	0.	277.0	0.0	846
ISOBUTYL TRICL ACETATE	219.50	1.2550	25.0	1.4456	0.0	0.	188.0	0.0	847
TETRAETGLYCOL DIME ETHER	222.29	1.0132	20.0	1.4336	-21.4	760.	275.8	0.0	848
1-HEXADECENE	224.42	0.7825	0.0	1.4441	4.0	0.	155.0	0.0	849
2-CLETHYL TRICL ACETATE	225.89	1.5357	20.0	1.4813	0.0	766.	217.0	0.0	850

Note: Missing data is indicated by 0, 0., or 0.0.

(continued)

Name	Mol. Wt.	Density	Temp.	Refract. Index	Melting Point	Pressure	Boiling Point	Dielec. Constant	List No.
TRICHLOROACETYL BROMIDE	226.29	0.1900	15.0	0.0	0.0	760.	143.0	0.0	851
TRI-N-PENTYLAMINE	227.44	0.7907	20.0	1.4367	-70.0	0.	242.5	0.0	852
DIBUTYL MALEATE	228.29	0.9950	20.0	1.4454	-80.0	0.	280.0	0.0	853
1,5-DIBROMOPENTANE	229.96	1.7060	18.0	1.5091	-39.5	0.	222.2	0.0	854
TRIBUTYL BORATE	230.16	0.8580	20.0	1.4092	-70.0	0.	233.5	0.0	855
DIISOPROPYL ADIPATE	230.31	0.9659	20.0	1.4247	-1.1	6.	120.0	0.0	856
DIPROPYL ADIPATE	230.31	0.9790	20.0	1.4314	-15.7	11.	151.0	0.0	857
DIPHENYL SELENIDE	233.17	1.3510	20.0	1.6500	2.5	760.	301.5	0.0	858
TETRAETHYL TIN	234.94	1.1870	23.0	1.4724	-112.0	0.	181.0	0.0	859
O-DIBROMOBENZENE	235.92	1.9557	0.0	1.6081	6.7	0.	221.0	0.0	860
M-DIBROMOBENZENE	235.92	1.9523	0.0	1.6083	-7.0	0.	220.0	0.0	861
1-IODO OCTANE	240.14	1.3297	0.0	1.4890	-45.7	0.	255.5	0.0	862
1,2-DIBROMOHEXANE	243.99	1.5872	15.0	1.5012	0.0	16.	287.0	0.0	863
DIETHYL AZELATE	244.33	0.9729	20.0	1.4351	-18.5	0.	291.5	0.0	864
TRICHLOROIODOMETHANE	245.30	2.3650	0.0	1.5854	-19.0	0.	142.0	0.0	865
4-BR-DIPHENYL ETHER	249.11	1.4225	19.0	1.6088	18.0	0.	305.0	0.0	866
BENZAL BROMIDE	249.95	1.5100	0.0	1.6147	0.0	0.	140.0	0.0	867
TRIBROMOACETALDEHYDE	250.76	2.6650	25.0	1.5939	0.0	760.	174.0	0.0	868
BROMOFORM	252.76	2.8889	20.0	1.5976	8.1	0.	149.6	4.39	869
1-IODO NAPHTHALENE	254.07	1.7399	20.0	1.7026	4.2	0.	302.0	0.0	870
DIBUTYL ADIPATE	258.35	0.9652	0.0	1.4369	-37.0	14.	183.0	0.0	871
DIBUTYL ADIPATE	258.36	0.9652	20.0	1.4369	-37.0	4.	145.0	0.0	872
DIETHYL SEBACATE	258.36	0.9646	20.0	1.4359	5.0	773.	306.0	0.0	873
DI ISOBUTYL ADIPATE	258.36	0.9530	20.0	1.4315	-17.0	760.	282.0	5.19	874
12DIBRTETF ETHANE	259.83	2.1630	25.0	1.3670	-110.5	0.	47.3	2.34	875
HEXACHLOROACETONE	264.77	1.7440	12.0	0.0	-30.0	0.	203.0	0.0	876
TRIBROMOETHYLENE	264.78	2.7080	20.5	1.6345	0.0	0.	163.5	0.0	877
1,1,2,3,4,4-HEXACLBUTANE	264.82	1.6460	20.0	1.5258	0.0	10.	111.0	0.0	878
TRI-N-BUTYL PHOSPHATE	266.32	0.9760	25.0	1.4226	-79.0	0.	289.0	7.96	879
1,1,2-TRIBROMOETHANE	266.79	2.5789	0.0	1.5933	-35.5	0.	188.5	0.0	880
TETRAMETHYL LEAD	267.33	1.9950	20.0	1.5120	-27.5	0.	110.0	0.0	881
DIIODOMETHANE	267.83	3.3078	25.0	1.7380	6.1	0.	182.0	5.32	882
DIBUTYL PHTHALATE	278.35	1.0465	20.0	1.4926	-35.0	0.	340.0	6.44	883
1,1,2-TRIBROMO PROPANE	280.80	2.3548	20.0	1.5790	0.0	760.	200.5	0.0	884
1,2,2-TRIBROMO PROPANE	280.80	2.2985	20.0	1.5670	0.0	760.	190.5	0.0	885
1,2,3-TRIBROMO PROPANE	280.80	2.4209	20.0	1.5862	16.9	760.	222.2	0.0	886
1,1-DIIODOETHANE	281.86	2.8400	0.0	1.6730	2.8	0.	179.5	0.0	887
OLEIC ACID	282.47	0.8870	25.0	1.4582	13.4	0.	360.0	2.46	888
1-BROMO-2-IODOBENZENE	282.92	2.2571	25.0	1.6618	8.0	0.	257.0	0.0	889
1-BROMO-3-IODOBENZENE	282.92	2.2220	25.0	1.6608	-9.0	754.	252.0	0.0	890
1-CHLOROOCTADECANE	288.95	0.8586	25.0	1.4525	19.0	2.	158.0	0.0	891
1-BROMOPENTADECANE	291.32	0.9999	25.0	1.4592	18.6	80.	172.0	0.0	892
123-TRIBR-2-ME PROPANE	294.65	2.1750	0.0	1.5652	0.0	0.	223.5	0.0	893
1,2,4-TRIBROMO BUTANE	294.83	2.1700	20.0	1.5608	-18.0	760.	215.0	0.0	894
2,2,3-TRIBROMO BUTANE	294.83	2.1724	20.0	1.5602	-1.9	760.	206.0	0.0	895
1,2,3-TRIBROMOBUTANE	294.84	2.1938	0.0	1.5680	-19.0	21.	113.5	0.0	896
METHYL OLEATE	296.50	0.8702	25.0	1.4502	19.9	0.	217.0	3.21	897
TRI-CL-ACETIC ANHYDRIDE	308.76	1.6908	20.0	0.0	0.0	760.	169.0	0.0	898
DI-N-BUTYL SEBACATE	314.47	0.9366	20.0	1.4397	1.0	0.	345.0	4.54	899
DIBUTYL SEBACATE	314.47	0.9324	25.0	1.4415	-11.0	0.	345.0	4.54	900
TETRAETHYL LEAD	323.45	1.6590	11.0	1.5915	-136.8	19.	91.0	0.0	901
N-BUTYL OLEATE	338.56	0.8657	25.0	1.4480	-10.0	0.	227.5	4.00	902
BUTYL STEARATE	340.60	0.8540	25.0	1.4422	26.3	0.	222.5	3.11	903
1122-TET BROMOETHANE	345.67	2.9529	25.0	1.6323	0.0	0.	243.5	7.00	904
1,1,1,2-TETRABROMOETHANE	345.70	2.8748	0.0	1.6277	0.0	0.	103.5	0.0	905
BIS(2-ETHOXY ET)SEBACATE	346.46	0.9953	25.0	1.4440	-10.0	0.	0.0	0.0	906
TRI(2-TOLYL)PHOSPHATE	368.36	1.1830	25.0	1.5575	11.0	20.	264.0	0.0	907
DI(2-ET HEX) ADIPATE	370.58	0.9220	25.0	1.4474	-67.8	5.	214.0	0.0	908
BIS(2-ETHEX)PHTHALATE	390.57	0.9843	20.0	1.4859	-50.0	0.	231.0	5.30	909
DIETHYLHEXYL AZELATE	412.66	0.9150	25.0	1.4460	-78.0	5.	237.0	0.0	910
BIS(2-ETHYLHEX)SEBACATE	426.66	0.9120	25.0	1.4510	-48.0	5.	256.0	4.03	911

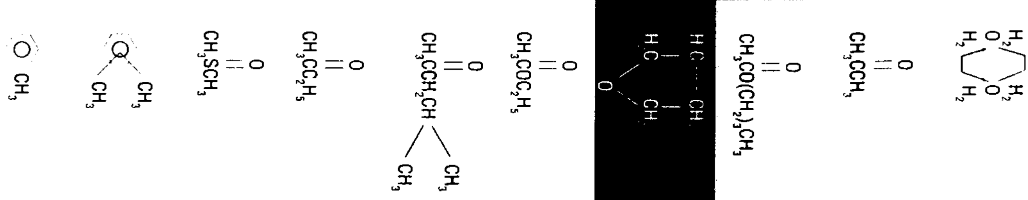
Note: Missing data is indicated by 0, 0., or 0.0.

Comparison of Solvent Properties *(11)*

Poorly Hydrogen-Bonded	benzene	carbon tetra-chloride	n-hexane	chloro-form	perchloro-ethylene	Freon® TF	Freon® MF	trichloro-ethylene	methyl formate	methylene chloride
Boiling Point, °C	80	77	68	61	121	48	24	87	31.8	39
°F	176	171	154	142	250	117.6	74.8	189	89.2	102
Freezing Point, °C	5.4	−23	−96	−64	−24	−35	−111	−73	−100	−96
°F	41	−9	−141	−83	−11	−31	−168	−99	−148	−142
Density, g/mL (mg/m³)	0.88	1.59	0.66	1.49	1.62	1.58	1.49	1.46	0.97	1.33
lb/gal	7.34	13.26	5.51	12.43	13.55	13.16	12.42	12.22	8.13	11.07
Vapor Density (air = 1)	2.8	5.3	2.97	4.1	5.8	—	—	4.54	2.1	2.93
Rate of Evaporation (Butyl acetate = 1)	6.30	12.80	10.00	11.60	2.80	9.87	13.07	6.20	~36	27.50
Viscosity, 20°C (68°F), cP (mPa·s)	0.65	0.99	0.29	0.57	0.88	0.70	0.41 (30°C)	0.58	0.35	0.44
Surface Tension in Air, 20°C (68°F), dyn/cm (mN/m)	28.9	26.8	18.4	27.2	32.3	19.0	18.7	32.0 (25°C)	25.0	28.2
Specific Heat, Liquid, 20°C (68°F), cal/g·C (Btu/lb·F)	0.42	0.21	0.54	0.23	0.21	0.22	0.21	0.23	0.516	0.28
kJ/kg·K	1.75	0.88	2.26	0.96	0.87	0.93	0.87	0.96	2.16	1.17
Heat of Vaporization (bp) cal/g	94	46	80	59	50	35.09	43.52	57	112.4	78
Btu/lb	170	84	145	106	90	63.12	78.31	103	202.3	141
kJ/kg	395	195	337	247	209	146.8	182.1	240	470.0	327
Solubility Parameter, δ	9.2	8.6	7.3	9.3	9.3	7.2	7.8	9.3	9.7	9.7
Hydrogen Bonding Index, γ	2.2	2.2	2.2	2.2	2.2	2.5	2.5	2.5	2.7	2.7
Flash Point, TCC, °C	−11	NF	−22	NF	NF	NF	NF	NF	−19	NF
°F	12		−7						−2	
Flammable Limits, vol% Lower	1.4	NF	1.2	NF	NF	NF	NF	NF	5	NF
Upper	8		6.9						23	
Threshold Limit Value,* ppm	10	5 skin	50	10	25	1000	1000 ceil.	50	100	50
Formula		CCl_4	$CH_3(CH_2)_4CH_3$	$CHCl_3$	$Cl_2C{:}CCl_2$	CCl_2FCClF_2	CCl_3F	$CHCl{:}CCl_2$	$H\overset{O}{\overset{\|}{C}}OCH_3$	CH_2Cl_2

(continued)

Moderately Hydrogen-Bonded

	toluene	mixed xylenes	dimethyl sulfoxide	MEK	MIBK	ethyl acetate	THF	n-butyl acetate	acetone	1,4-dioxane
Boiling Point, °C	111	135	189	79	117	77	66	125	56	101
°F	231	275	372	175	243	171	151	257	133	214
Freezing Point, °C	−95	—	18	−87	−85	−84	−108.5	−76	−94	10
°F	−139	—	65	−124	−121	−119	−163	−105	−137	50
Density, g/mL (mg/m³)	0.87	0.87	1.10	0.80	0.80	0.90	0.89	0.88	0.79	1.04
lb/gal	7.25	7.24	9.18	6.71	6.68	7.51	7.41	7.34	6.58	8.60
Vapor Density (air = 1)	3.1	1.1	—	2.5	3.5	3.04	2.49	4.0	2.0	3.0
Rate of Evaporation (Butyl acetate = 1)	2.4	0.7	9.2	5.72	1.65	6.15	8.0	1.00	11.60	3.11
Viscosity, 20°C (68°F), cP (mPa·s)	0.59	0.69	1.98 (25°C)	0.42	0.59	0.44	0.48	0.74	0.35	1.31
Surface Tension in Air, 20°C (68°F), dyn/cm (mN/m)	28.4	28.9	43.5	24.6	22.7	23.9	26.4 (25°C)	27.6 (27°C)	23.7	33.4
Specific Heat, Liquid, 20°C (68°F), cal/g·C (Btu/lb·F)	0.39	0.40	0.47 (29°C)	0.55	0.50	0.46	0.469	0.51	0.51	0.41
kJ/kg·K	1.63	1.67	1.97	2.30	2.09	1.92	1.97	2.13	2.13	1.72
Heat of Vaporization (bp) cal/g	87	82	144	106	87	88	95	74	124	98
Btu/lb	156	147	260	191	157	158	171	133	224	177
kJ/kg	362	342	604	444	365	367	398	309	521	412
Solubility Parameter, δ	8.9	8.8	13.0	9.3	8.4	9.1	9.1	8.5	10	9.9
Hydrogen Bonding Index, γ	3.8	3.8	5.0	5.0	5.0	5.2	5.3	5.4	5.7	5.7
Flash Point, TCC, °C	4	27	95 (TOC)	−7	23	−4	−14	27	−18	12
°F	40	80	203	20	73	24	6	81	0	54
Flammable Limits, vol% Lower	1.2	1.1	2.6	1.8	1.4	2.2	2	1.4	3	2
Upper	7.1	7.0	28.5	10	7.5	11	11.8	7.6	13	22.2
Threshold Limit Value,* ppm	50 skin	100	—	200	50	400	200	150	750 (500 proposed)	25 skin
Formula										

(continued)

Strongly Hydrogen-Bonded

	cyclo-hexanone	DMF	DMAC	EGME	ethyl ether	methanol	ethanol 95%	isopropyl alcohol	n-butyl alcohol	formamide
Boiling Point, °C	157	153	166.1	124	34	65	75.0	82	118	210
°F	315	307	331	255	94	148	167	180	244	410
Freezing Point, °C	–31.2	–61	–20	–85	–123	–98	–128.0	–89	–89.8	3
°F	–24	–78	–4	–121	–189	–144	–198.4	–128	–130	36
Density, g/mL (mg/m³)	0.94	0.90	0.945	0.96	0.71	0.79	0.812	0.78	0.81	1.13
lb/gal	7.88	7.50	7.88	8.04	5.92	6.63	6.74	6.55	6.76	9.46
Vapor Density (air = 1)	3.4	2.51	3.0	2.62	2.55	1.11	1.59	2.07	2.55	—
Rate of Evaporation (Butyl acetate = 1)	0.23	0.17	<1	0.47	33.00	6.10	1.7	2.30	0.45	<1
Viscosity, 20°C (68°F), cP (mPa·s)	2.2	0.80	0.92 (25°C)	1.72	0.23	0.59	1.2	2.4	2.7	3.76
Surface Tension in Air, 20°C (68°F), dyn/cm (mN/m)	34.5	35.2 (25°C)	32.4 (30°C)	35.0 (25°C)	17.0	22.6	22.8	21.7	24.6	58.4
Specific Heat, Liquid, 20°C (68°F), cal/g·C (Btu/lb·F)	0.49	0.49	0.48	0.53	0.55	0.60	0.62	0.60	0.56	0.551
kJ/kg·K	2.05	2.05	2.01	2.22	2.30	2.51	2.59	2.51	2.34	2.31
Heat of Vaporization (bp) cal/g	109	138	119	135	84	263	—	160	141	400
Btu/lb	197 (29°C)	248	214	243	151	473	—	287	254	720
kJ/kg	458	576	498	565	351	1100	—	668	591	1674
Solubility Parameter, δ	9.9	12.1	10.8	10.8	7.4	14.5	13.6	11.5	11.4	19.2
Hydrogen Bonding Index, γ	6.4	6.4	6.6	6.9	6.9	8.9	8.9	8.9	8.9	>16.2
Flash Point, TCC, °C	44	58	63	46	–45	11	14	12	29	155 (TOC)
°F	111	136	145	115	–49	52	57	53	84	310 (TOC)
Flammable Limits, vol% Lower	1.1	2.2 (100°C)	1.8 (100°C)	2.5	1.9	6.7	3.3	2.3	1.4	1.5
Upper	8.1	15.2	8.6 (20°C)	14	48	36	19.0	12.7	11	12
Threshold Limit Value,* ppm	25 skin	10 skin	10 skin	5 skin	400	200 skin	1000	400	50 ceil. skin (25 ceil. proposed)	10 skin
Formula		$(CH_3)_2NCH{=}O$	$(CH_3)_2NC(CH_3){=}O$	$CH_3O(CH_2)_2OH$	$C_2H_5OC_2H_5$	CH_3OH	C_2H_5OH	$(CH_3)_2CHOH$	$CH_3(CH_2)_3OH$	$HC(=O)NH_2$

Fats and Oils Composition *(26)*

		FATS AND OILS COMPOSITION							
		VEGETABLE BASED							
FATTY ACID COMPONENT		CANOLA	CASTOR	COCO BUTTER	COCONUT	CORN	COTTON SEED	CRAMBE	LINSEED
C4	**BUTANOIC (Butyric)**								
C6	**HEXANOIC (Caproic)**								
C8	**OCTANOIC (Caprylic)**				**7.6**				
C10	DECANOIC (Capric)				7.3				
C10:1	DECENOIC								
TOTAL C10					**7.3**				
C12	LAURIC (Dodecanoic)				48.2		0.1		
C12:1	cis-9-DODECENOIC								
TOTAL C12					**48.2**		**0.1**		
C14	MYRISTIC (Tetradecanoic)			0.5	16.6		0.7		
C 14:1	cis-9-TETRADECENOIC								
TOTAL C14				**0.5**	**16.6**		**0.7**		
C15	PENTADECANOIC								
TOTAL C15									
C16	PALMITIC (Hexadecanoic)	3.2	1.2	25.0	8.0	11.5	21.6	2.0	5.5
C16:1	cis-9-HEXADECENOIC		0.2		1.0		0.6	0.4	
TOTAL C16		**3.2**	**1.4**	**25.0**	**9.0**	**11.5**	**22.2**	**2.4**	**5.5**
C17	HEPTADECANOIC						0.1		
C17:1	HEPTADECENOIC						0.1		
TOTAL C17							**0.2**		
C18	STEARIC (Octadecanoic)	0.9	1.0	34.5	3.8	2.2	2.6	0.4	3.5
C18:1	OLEIC (cis-9-Octadecenoic)	66.8	3.0	36.5	5.0	26.6	18.6	16.9	19.1
C18:2	LINOLEIC (cis-9, cis-12-Octadecadienoic)	19.0	3.5	3.0	2.5	58.7	54.4	8.6	15.3
C18:3	LINOLENIC (cis-9, cis-12, cis-15-Octadecatrienoic)	9.1	0.2	0.5		0.8	0.7	6.4	56.6
C18:4	cis-6, cis-9, cis-12, cis-15-OCTADECATETRAENOIC								
C18:1 (OH)	RICINOLEIC (12-Hydroxy-cis-9-Octadecenoic)		89.2						
C18 $(OH)_2$	DIHYDROXYSTEARIC		1.4						
TOTAL C18		**95.8**	**98.3**	**74.5**	**11.3**	**88.3**	**76.3**	**32.3**	**94.5**
C19	NONADECANOIC								
TOTAL C19									
C20	EICOSANOIC (Arachidic)		0.3			0.2	0.3	0.5	
C20:1	cis-9 or cis-11-EICOSENOIC							3.2	
C20:2	EICOSADIENOIC								
C20 3	EICOSATRIENOIC								
C20:4	ARACHIDONIC (cis-5, cis-8, cis-11, cis-14-Eicosatetraenoic)								
C20:5	EICOSAPENTAENOIC								
TOTAL C20			**0.3**			**0.2**	**0.3**	**3.7**	
C22	DOCOSANOIC (Behenic)						0.2	2.0	
C22:1	cis-13-DOCOSENOIC (Erucic)	1.0						57.2	
C22:2	DOCOSADIENOIC							0.8	
C22:5	4, 8, 12, 15, 19-DOCOSAPENTAENOIC								
C22:6	DOCOSAHEXAENOIC								
TOTAL C22		**1.0**					**0.2**	**60.0**	
C24	TETRACOSANOIC (Lignoceric)								
C24:1	TETRACOSENOIC								
TOTAL C24									
Others								**1.6**	
TOTAL		**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Note: Typical % composition determined by chromatography. Some values obtained from literature.

Chemical Values

	CANOLA	CASTOR	COCO BUTTER	COCONUT	CORN	COTTON SEED	CRAMBE	LINSEED
IODINE VALUE	94-126	81-91	81-91	7-12	118-128	98-118	91	155-205
SAP VALUE OF OIL	186-198	176-187	177-187	250-264	187-193	189-198	169	188-196
MELTING POINT, °C		-20 to -10		23-26	-12 to -10	-2 to 2		-20
TITER, (OF SPLIT ACIDS) °C	0-2	1-3	1-3.5	20-24	14-20	30-37		19-21

Note: Some values obtained from literature.

(continued)

Fats and Oils Composition

FATTY ACID COMPONENT		VEGETABLE BASED: OLIVE	PALM KERNEL	PALM KERNEL: OLEIN	PALM KERNEL: STEARINE	PALM OIL	PALM OIL: OLEIN	PALM OIL: STEARINE
C4	**BUTANOIC (Butyric)**							
C6	**HEXANOIC (Caproic)**			**0.2**	**0.1**			
C8	**OCTANOIC (Caprylic)**		**1.4**	**4.3**	**2.4**			
C10	DECANOIC (Capric)		2.9	3.7	3.2			
C10:1	DECENOIC							
TOTAL C10			**2.9**	**3.7**	**3.2**			
C12	LAURIC (Dodecanoic)		50.9	42.6	55.2	0.3	0.2	0.7
C12:1	cis-9-DODECENOIC							
TOTAL C12			**50.9**	**42.6**	**55.2**	**0.3**	**0.2**	**0.7**
C14	MYRISTIC (Tetradecanoic)		18.4	12.4	19.9	1.1	1.0	1.5
C 14:1	cis-9-TETRADECENOIC							
TOTAL C14			**18.4**	**12.4**	**19.9**	**1.1**	**1.0**	**1.5**
C15	PENTADECANOIC							
TOTAL C15								
C16	PALMITIC (Hexadecanoic)	9.0	8.7	8.4	8.1	42.9	39.8	55.7
C16:1	cis-9-HEXADECENOIC	0.6				0.2	0.2	
TOTAL C16		**9.6**	**8.7**	**8.4**	**8.1**	**43.1**	**40.0**	**55.7**
C17	HEPTADECANOIC					0.1		
C17:1	HEPTADECENOIC							
TOTAL C17						**0.1**		
C18	STEARIC (Octadecanoic)	2.7	1.9	2.5	3.3	4.6	4.4	4.8
C18:1	OLEIC (cis-9-Octadecenoic)	80.3	14.6	22.3	6.9	39.3	42.5	29.5
C18:2	LINOLEIC (cis-9, cis-12-Octadecadienoic)	6.3	1.2	3.4	0.8	10.7	11.2	7.2
C18:3	LINOLENIC (cis-9, cis-12, cis-15-Octadecatrienoic)	0.7				0.4	0.2	0.1
C18:4	cis-6, cis-9, cis-12, cis-15-OCTADECATETRAENOIC							
C18:1 (OH)	RICINOLEIC (12-Hydroxy-cis-9-Octadecenoic)							
C18 $(OH)_2$	DIHYDROXYSTEARIC							
TOTAL C18		**90.0**	**17.7**	**28.2**	**11.0**	**55.0**	**58.3**	**41.6**
C19	NONADECANOIC							
TOTAL C19								
C20	EICOSANOIC (Arachidic)	0.4		0.1	0.1	0.3	0.4	0.4
C20:1	cis-9 or cis-11-EICOSENOIC			0.1				
C20:2	EICOSADIENOIC							
C20 3	EICOSATRIENOIC							
C20:4	ARACHIDONIC (cis-5, cis-8, cis-11, cis-14-Eicosatetraenoic)							
C20:5	EICOSAPENTAENOIC							
TOTAL C20		**0.4**		**0.2**	**0.1**	**0.3**	**0.4**	**0.4**
C22	DOCOSANOIC (Behenic)					0.1	0.1	0.1
C22:1	cis-13-DOCOSENOIC (Erucic)							
C22:2	DOCOSADIENOIC							
C22:5	4, 8, 12, 15, 19-DOCOSAPENTAENOIC							
C22:6	DOCOSAHEXAENOIC							
TOTAL C22						**0.1**	**0.1**	**0.1**
C24	TETRACOSANOIC (Lignoceric)							
C24:1	TETRACOSENOIC							
TOTAL C24								
Others								
TOTAL		100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Typical % composition determined by chromatography. Some values

Chemical Values

IODINE VALUE	80-88	14-19	25-31	6-9	50-55	56 Min	48 Max
SAP VALUE OF OIL	188-196	245-255			196-202		
MELTING POINT, °C		24-26			27-50		24-26
TITER, (OF SPLIT ACIDS) °C	17-26	20-28		32	40-47		20-26

Note: Some values obtained from literature.

(continued)

Fats and Oils Composition

VEGETABLE BASED

FATTY ACID COMPONENT		PEANUT	RAPE SEED	SAFFLOWER	SOYBEAN	SUNFLOWER	TALL OIL
C4	**BUTANOIC (Butyric)**						
C6	**HEXANOIC (Caproic)**						
C8	**OCTANOIC (Caprylic)**						
C10	DECANOIC (Capric)						
C10:1	DECENOIC						
TOTAL C10							
C12	LAURIC (Dodecanoic)						
C12:1	cis-9-DODECENOIC						
TOTAL C12							
C14	MYRISTIC (Tetradecanoic)	0.1	0.1		0.1		
C 14:1	cis-9-TETRADECENOIC						
TOTAL C14		**0.1**	**0.1**		**0.1**		
C15	PENTADECANOIC						
TOTAL C15							
C16	PALMITIC (Hexadecanoic)	11.1	4.0	6.5	10.5	7.0	0.2
C16:1	cis-9-HEXADECENOIC	0.2	0.1				
TOTAL C16		**11.3**	**4.1**	**6.5**	**10.5**	**7.0**	**0.2**
C17	HEPTADECANOIC	0.1					
C17:1	HEPTADECENOIC	0.1					
TOTAL C17		**0.2**					
C18	STEARIC (Octadecanoic)	2.4	1.3	2.5	3.2	3.3	2.2
C18:1	OLEIC (cis-9-Octadecenoic)	46.7	17.6	12.5	22.3	21.0	58.6
C18:2	LINOLEIC (cis-9, cis-12-Octadecadienoic)	32.0	12.7	77.5	54.5	68.0	36.0
C18:3	LINOLENIC (cis-9, cis-12, cis-15-Octadecatrienoic)		5.3		8.3	0.7	
C18:4	cis-6, cis-9, cis-12, cis-15-OCTADECATETRAENOIC						
C18:1 (OH)	RICINOLEIC (12-Hydroxy-cis-9-Octadecenoic)						
C18 $(OH)_2$	DIHYDROXYSTEARIC						
TOTAL C18		**81.1**	**36.9**	**92.5**	**88.3**	**93.0**	**96.8**
C19	NONADECANOIC						
TOTAL C19							
C20	EICOSANOIC (Arachidic)	1.3	0.9	0.5	0.2		0.7
C20:1	cis-9 or cis-11-EICOSENOIC	1.6	10.6	0.5	0.9		0.7
C20:2	EICOSADIENOIC						
C20 3	EICOSATRIENOIC						
C20:4	ARACHIDONIC (cis-5, cis-8, cis-11, cis-14-Eicosatetraenoic)						
C20:5	EICOSAPENTAENOIC						
TOTAL C20		**2.9**	**11.5**	**1.0**	**1.1**		**1.4**
C22	DOCOSANOIC (Behenic)	2.9	0.7				
C22:1	cis-13-DOCOSENOIC (Erucic)		45.8				
C22:2	DOCOSADIENOIC		0.1				
C22:5	4, 8, 12, 15, 19-DOCOSAPENTAENOIC						
C22:6	DOCOSAHEXAENOIC						
TOTAL C22		**2.9**	**46.8**				
C24	TETRACOSANOIC (Lignoceric)	1.5	0.2				
C24:1	TETRACOSENOIC		0.6				
TOTAL C24		**1.5**	**0.8**				
Others							**1.6**
TOTAL		**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Note: Typical % composition determined by chromatography. Some values

Chemical Values

	PEANUT	RAPE SEED	SAFFLOWER	SOYBEAN	SUNFLOWER	TALL OIL
IODINE VALUE	84-100	100-110	140 150	120-141	125-136	122-142
SAP VALUE OF OIL	188-195	183-188	188 194	189-195	188-194	197-200
MELTING POINT, °C	-2	-7 to 10	18 to 16	-23 to -20	-18 to -16	
TITER, (OF SPLIT ACIDS) °C	26-32	23 26	16 18	20 21	16-20	4-15

Note: Some values obtained from literature.

(continued)

FATTY ACID COMPONENT		ANIMAL BASED BUTTER	LARD	TALLOW	YELLOW GREASE
C4	**BUTANOIC (Butyric)**	**2.3**			
C6	**HEXANOIC (Caproic)**	**1.6**			
C8	**OCTANOIC (Caprylic)**	**1.5**			
C10	DECANOIC (Capric)	2.2			
C10:1	DECENOIC	0.4			
TOTAL C10		**2.6**			
C12	LAURIC (Dodecanoic)	2.5	0.3		
C12:1	cis-9-DODECENOIC	0.2			
TOTAL C12		**2.7**	**0.3**		
C14	MYRISTIC (Tetradecanoic)	8.2	1.7	3.0	2.6
C 14:1	cis-9-TETRADECENOIC	2.6	0.2	0.4	0.3
TOTAL C14		**10.8**	**1.9**	**3.4**	**2.9**
C15	PENTADECANOIC		0.1		
TOTAL C15			**0.1**		
C16	PALMITIC (Hexadecanoic)	25.8	26.2	26.3	26.3
C16:1	cis-9-HEXADECENOIC	4.6	4.0	2.6	3.2
TOTAL C16		**30.4**	**30.2**	**28.9**	**29.5**
C17	HEPTADECANOIC		0.5	0.4	0.3
C17:1	HEPTADECENOIC		0.3	0.4	
TOTAL C17			**0.8**	**0.8**	**0.3**
C18	STEARIC (Octadecanoic)	9.1	13.5	22.4	18.4
C18:1	OLEIC (cis-9-Octadecenoic)	32.1	42.9	43.1	45.3
C18:2	LINOLEIC (cis-9, cis-12-Octadecadienoic)	4.9	9.0	1.4	3.6
C18:3	LINOLENIC (cis-9, cis-12, cis-15-Octadecatrienoic)	2.0	0.3		
C18:4	cis-6, cis-9, cis-12, cis-15-OCTADECATETRAENOIC				
C18:1 (OH)	RICINOLEIC (12-Hydroxy-cis-9-Octadecenoic)				
C18 (OH)₂	DIHYDROXYSTEARIC				
TOTAL C18		**48.1**	**65.7**	**66.9**	**67.3**
C19	NONADECANOIC				
TOTAL C19					
C20	EICOSANOIC (Arachidic)		0.2		
C20:1	cis-9 or cis-11-EICOSENOIC		0.8		
C20:2	EICOSADIENOIC				
C20 3	EICOSATRIENOIC				
C20:4	ARACHIDONIC (cis-5, cis-8, cis-11, cis-14-Eicosatetraenoic)				
C20:5	EICOSAPENTAENOIC				
TOTAL C20			**1.0**		
C22	DOCOSANOIC (Behenic)				
C22:1	cis-13-DOCOSENOIC (Erucic)				
C22:2	DOCOSADIENOIC				
C22:5	4, 8, 12, 15, 19-DOCOSAPENTAENOIC				
C22:6	DOCOSAHEXAENOIC				
TOTAL C22					
C24	TETRACOSANOIC (Lignoceric)				
C24:1	TETRACOSENOIC				
TOTAL C24					
Others					
TOTAL		100.0	100.0	100.0	100.0

Note: Typical % composition determined by chromatography. Some values

Chemical Values

	BUTTER	LARD	TALLOW	YELLOW GREASE
IODINE VALUE	25-42	53-57	48-52	50-65
SAP VALUE OF OIL	233-240	190-202	192-202	190-202
MELTING POINT, °C	28-35	33-46	40-47	
TITER, (OF SPLIT ACIDS) °C	33-38	32-43	40-47	39-43

Note: Some values obtained from literature.

(continued)

FATTY ACID COMPONENT		MARINE BASED			
		HERRING	MENHADEN	SARDINE	
C4	**BUTANOIC (Butyric)**				**C4**
C6	**HEXANOIC (Caproic)**				**C6**
C8	**OCTANOIC (Caprylic)**				**C8**
C10	DECANOIC (Capric)				C10
C10:1	DECENOIC				C10:1
TOTAL C10					**TOTAL C10**
C12	LAURIC (Dodecanoic)				C12
C12:1	cis-9-DODECENOIC				C12:1
TOTAL C12					**TOTAL C12**
C14	MYRISTIC (Tetradecanoic)	7.6	7.3	6.0	C14
C 14:1	cis-9-TETRADECENOIC				C14:1
TOTAL C14		**7.6**	**7.3**	**6.0**	**TOTAL C14**
C15	PENTADECANOIC	0.4	0.4		C15
TOTAL C15		**0.4**	**0.4**		**TOTAL C15**
C16	PALMITIC (Hexadecanoic)	18.3	23.6	10.0	C16
C16:1	cis-9-HEXADECENOIC	8.3	9.9	13.0	C16:1
TOTAL C16		**26.6**	**33.5**	**23.0**	**TOTAL C16**
C17	HEPTADECANOIC	0.5	0.9		C17
C17:1	HEPTADECENOIC				C17:1
TOTAL C17		**0.5**	**0.9**		**TOTAL C17**
C18	STEARIC (Octadecanoic)	2.2	2.6	2.0	C18
C18:1	OLEIC (cis-9-Octadecenoic)	16.9	17.0	24.0	C18:1
C18:2	LINOLEIC (cis-9, cis-12-Octadecadienoic)	1.6	1.2		C18:2
C18:3	LINOLENIC (cis-9, cis-12, cis-15-Octadecatrienoic)	0.6			C18:3
C18:4	cis-6, cis-9, cis-12, cis-15-OCTADECATETRAENOIC		4.1		C18:4
C18:1 (OH)	RICINOLEIC (12-Hydroxy-cis-9-Octadecenoic)				C18:1 (OH)
C18 (OH)₂	DIHYDROXYSTEARIC				C18 (OH)₂
TOTAL C18		**21.3**	**24.9**	**26.0**	**TOTAL C18**
C19	NONADECANOIC		1.2		C19
TOTAL C19			**1.2**		**TOTAL C19**
C20	EICOSANOIC (Arachidic)				C20
C20:1	cis-9 or cis-11-EICOSENOIC	9.4			C20:1
C20:2	EICOSADIENOIC		0.3		C20:2
C20 3	EICOSATRIENOIC		0.2		C20:3
C20:4	ARACHIDONIC (cis-5, cis-8, cis-11, cis-14-Eicosatetraenoic)	0.4	3.4	26.0	C20:4
C20:5	EICOSAPENTAENOIC	8.6	12.0		C20:5
TOTAL C20		**18.4**	**15.9**	**26.0**	**TOTAL C20**
C22	DOCOSANOIC (Behenic)				C22
C22:1	cis-13-DOCOSENOIC (Erucic)	11.6			C22:1
C22:2	DOCOSADIENOIC		1.7		C22:2
C22:5	4, 8, 12, 15, 19-DOCOSAPENTAENOIC	1.3	9.1	19.0	C22:5
C22:6	DOCOSAHEXAENOIC	7.6			C22:6
TOTAL C22		**20.5**	**10.8**	**19.0**	**TOTAL C22**
C24	TETRACOSANOIC (Lignoceric)				C24
C24:1	TETRACOSENOIC	0.4	0.8		C24:1
TOTAL C24		**0.4**	**0.8**		**TOTAL C24**
Others		**4.3**	**4.3**		**Others**
TOTAL		**100.0**	**100.0**	**100.0**	

Note: Typical % composition determined by chromatography. Some values

Chemical Values

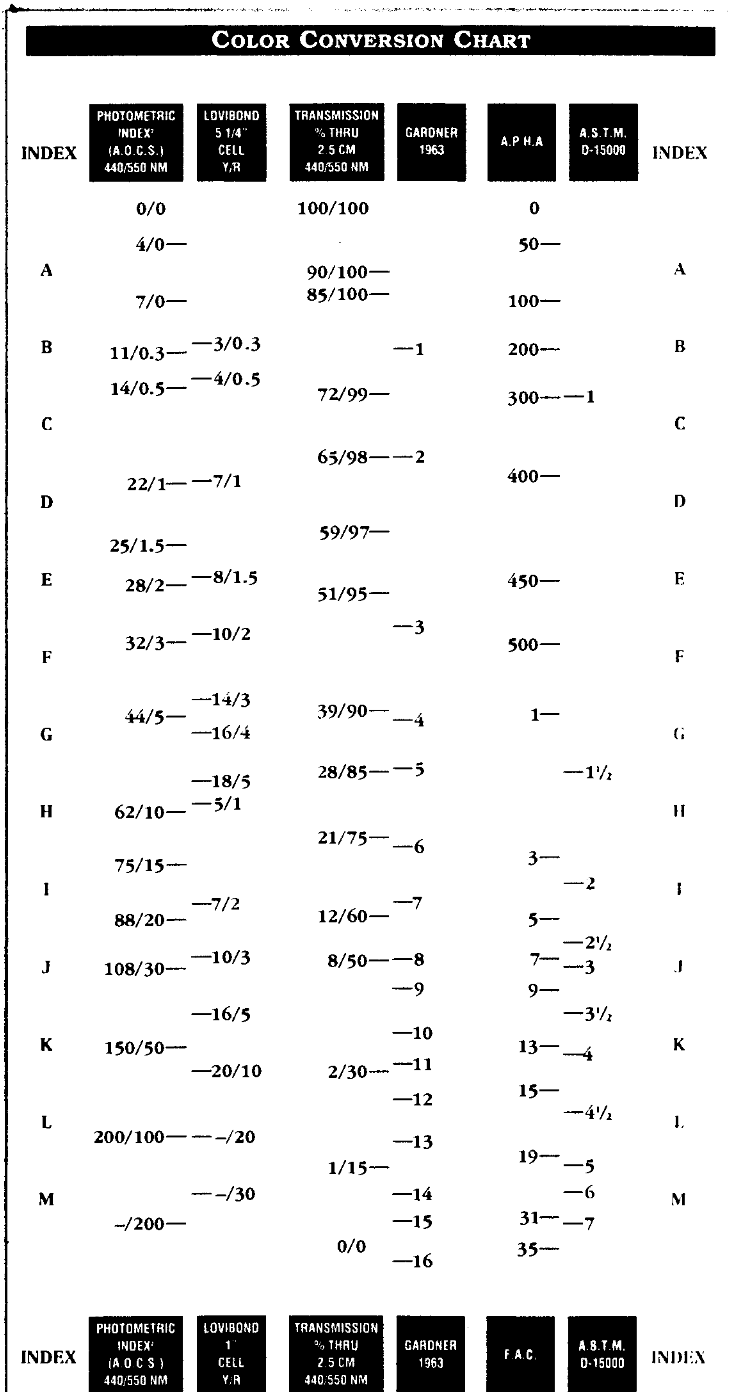
IODINE VALUE	123-142	140-188	170-193
SAP VALUE OF OIL	180-192	189-193	189-193
MELTING POINT, °C			
TITER, (OF SPLIT ACIDS) °C	23-27	27-28	31-33

Note: Some values obtained from literature.

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(continued)

Color Conversion Chart *(26)*



1. Comparisons of color scales of different systems are very difficult and inaccurate. Thus, this conversion chart should be used only for fatty acids and only to obtain approximate values.

2. Absorbency readings were taken on Coleman 6A Spectrophotometer using 25mm Cuvette.

Viscosity Conversions *(41)*

VISCOSITY CONVERSIONS (For Newtonian Fluids, @ 25°C, D = 1)						
Centipoises	Ford Cup #4	Zahn #2	Zahn #3	Zahn #4	Gardner Holdt	Krebs Stormer
1.0					A-5	
10.0		16			A-4	
15.0		17			A-3	
22.0	14	19			A-2	
32.0	15	20			A-1	
50.0	19	22			A	
65.0	22	27			B	
85.0	27	34			C	
100.0	30	41	12		D	
125.0	36	49	14	11	E	
140.0	40	58	16	13	F	
165.0	46	66	18	14	G	
200.0	50	82	23	17	H	52
225.0	55		25	18	I	54
250.0	68		27	20	J	56
275.0	74		32	22	K	59
300.0	81		34	24	L	61
320.0	86		36	25	M	62
340.0	91		39	26	N	63
370.0	99		41	28	O	64
400.0	107		46	30	P	65
435.0	116		50	33	Q	66
470.0	125		52	34	R	67
500.0	133		57	37	S	68
550.0	146		63	40	T	69
630.0	167		68	44	U	71
885.0	199			64	V	78
1,070.0	270				W	85
1,290.0					X	95
1,760.0					Y	100
2,270.0					Z	105
2,700.0					Z-1	114
3,620.0					Z-2	129
4,630.0					Z-3	136
6,340.0					Z-4	
9,850.0					Z-5	
14,800.0					Z-6	

Density of Water at Various Temperatures *(23)*

Density of Water at Various Temperatures	
Temperature, °C	Density, g/ml
-20	0.99349
-10	0.998137
0	0.999868
1	0.999927
2	0.999968
3	0.999992
4	1.000000
5	0.999992
6	0.999968
7	0.999930
8	0.999877
9	0.999809
10	0.999728
15	0.999129
20	0.998234
25	0.997075
30	0.995678
35	0.994063
40	0.992247
50	0.988066
60	0.983226
70	0.977793
80	0.971819
90	0.965340
95	0.961920
100	0.958384

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(9) Elf Atochem Inc., 266 Harristown Rd., P.O. Box 607, Glen Rock, NJ 07452, (201-652-8575/800-932-0420)
(10) Eastman Chemical Co., P.O. Box 431, Kingsport, TN 37662, (800-EASTMAN)
(11) DuPont Co., Wilmington, DE 19898, (800-441-9408)
(12) Sun Refining and Marketing Co., Ten Penn Center, 1801 Market St., Philadelphia, PA 19103, (215-977-3513/800-825-3535
(13) Unocal Corp., 1701 Golf Rd., Rolling Meadows, IL 60008, (800-967-7601/800-964-7676)
(14) Shell Chemical Co., 3200 Southwest Freeway, Suite 1230, Houston, TX 77027, (713-241-8101)
(15) CPS Chemical Co., Inc., P.O. Box 162, Old Bridge, NJ 08857, (908-607-2700)
(16) Castrol Industries, 1000 W. 31st St., Downers Grove, IL 60515
(17) Allied-Signal, Inc., Engineered Solvent, P.O. Box 1139R, Morristown, NJ 07962, (201-455-2120/800-922-0964)
(18) Penreco, 138 Petrolia St., Karns City, PA 16041, (412-756-0110/800-245-3952)
(19) Union Carbide Corp., 39 Old Ridgebury Rd., Danbury, CT 06817, (800-SOLVENT)
(20) Amoco Chemicals, 801 Warrenville Rd., Lisle, IL 60532, (800-621-4567)
(21) Grant Chemical Division, Ferro Corp., P.O. Box 263, Baton Rouge, LA 70821, (504-654-6801)
(22) PPG Industries, Inc. One PPG Place, Pittsburgh, PA 15272, (412-434-3131/800-CHEM-PPG)
(23) Dow Chemical Co., Midland, MI 48674, (800-447-4369)
(24) Rhone-Poulenc Basic Chemicals Corp., One Corporate Dr., Box 881, Shelton, CT 06484, (203-925-3300)
(25) Halocarbon Products Corp., 887 Kinderkamack Rd., River Edge, NJ 07661, (201-262-8899)
(26) Humko Chemical Division, Witco Corp., P.O. Box 125, Memphis, TN 38101-0125, (901-320-5800)
(27) Occidental Chemical Corp., Occidental Tower, 5005 LBJ Freeway, Dallas, TX 75244, (972-404-3700/800-733-9960)
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(39) Procter & Gamble, Industrial Chemical Div., P.O. Box 599, Cincinnati, OH 45201, (513-983-5607/800-543-1580)
(40) Vista Chemical Co., 900 Threadneedle, P.O. Box 19029, Houston, TX 77224, (713-588-3000/800-231-8212)
(41) Eastman Kodak Co., 343 State St., Rochester, NY 14650, (800-225-5352)
(42) Hoechst Celanese Corp., 1601 West LBJ Freeway, Dallas, TX 75234, (214-277-4000)
(43) SCM Glidco Organics Corp., P.O. Box 389, Jacksonville, FL 32201, (904-768-5800/800-231-6728)
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(45) Sonneborn Division, Witco Corp., 520 Madison Ave., New York, NY 10022-4236, (212-605-3911/800-634-4010)
(46) QO Chemicals, Inc., P.O. Box 2500, West Lafayette, IN 47906, (317-497-6100/800-621-9521)
(47) BASF Corp., 3000 Continental Dr. N., Mt. Olive, NJ 07828, (800-443-6460)
(48) Huntsman Corp. (formerly Texaco), P.O. Box 27707, Houston, TX 77227, (713-235-6000)
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(54) 3M Adhesive Systems, 3M Center, St. Paul, MN 55144, (612-733-1110)
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(59) Akzo Chemicals Inc., 300 S. Riverside Plaza, Chicago, IL 60606, (312-906-7500/800-257-8292)
(60) Crowley Chemical Co., Inc. 261 Madison Ave., New York, NY 10016, (212-682-1200)
(61) Baxter Healthcare Corp., Burdick & Jackson Div., 1953 S. Harvey St., Muskegon, MI 49442, (616-726-3171/800-368-0050)
(62) Alpha Metals, Inc., 600 Route 440, Jersey City, NJ 07304, (201-434-6778)
(63) Henkel Corp., Emery Group, 5051 Estercreek Dr., Cincinnati, OH 45232, (513-482-3000)
(64) Mobil Oil Corp., 3225 Gallows Rd., Fairfax, VA 22037, (800-662-4525)
(65) Kendall/ Amalie Division, Witco Corp., 77 N. Kendall Ave., Bradford, PA 16701, (814-368-6111)
(66) Olin Chemicals, 120 Long Ridge Rd., Stamford, CT 06904, (203-356-3000/800-243-9171)
(67) Chemcentral Corp., P.O. Box 730, Chicago (Bedford Park), IL 60499, (800-331-6174)
(68) Stepan Co., 22 W. Frontage Rd., Northfield, IL 60093, (708-446-7500/800-745-7837)
(69) Ashland Chemical Co., ICS Division, P.O. Box 2219, Columbus, OH 43216, (614-790-3333)
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(76) FMC Corp., 1735 Market St., Philadelphia, PA 19103, (800-468-3853)
(77) Witco Corp., One American La., Greenwich, CT 06831, (800-494-8287)
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